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PREFACE

We desire to make the following acknowledgments :—to Dr. H. H. Mann, Director of Agriculture, Bombay Presidency, for the inspiration derived from his continuous interest and personal criticism ; to Mr. E. J. Bruen, Live Stock Expert to Bombay Government, for granting us facilities to work on the farms under his control, and for many practical suggestions ; to Mr. V. A. Tahmane, M.Ag., M.Sc., Soil Physicist to Bombay Government, for much help in the Soil Laboratories ; to Mr. D. V. Narayanayya, Assistant Economic Botanist, for much help in the preparation of drawings and photographs ; and to Mr. R. B. Deshpande, B.Ag., who has been associated with us in the latter stages of this work and who has made the special study of *Andropogon contortus*.

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Poona ;
April 20, 1925.

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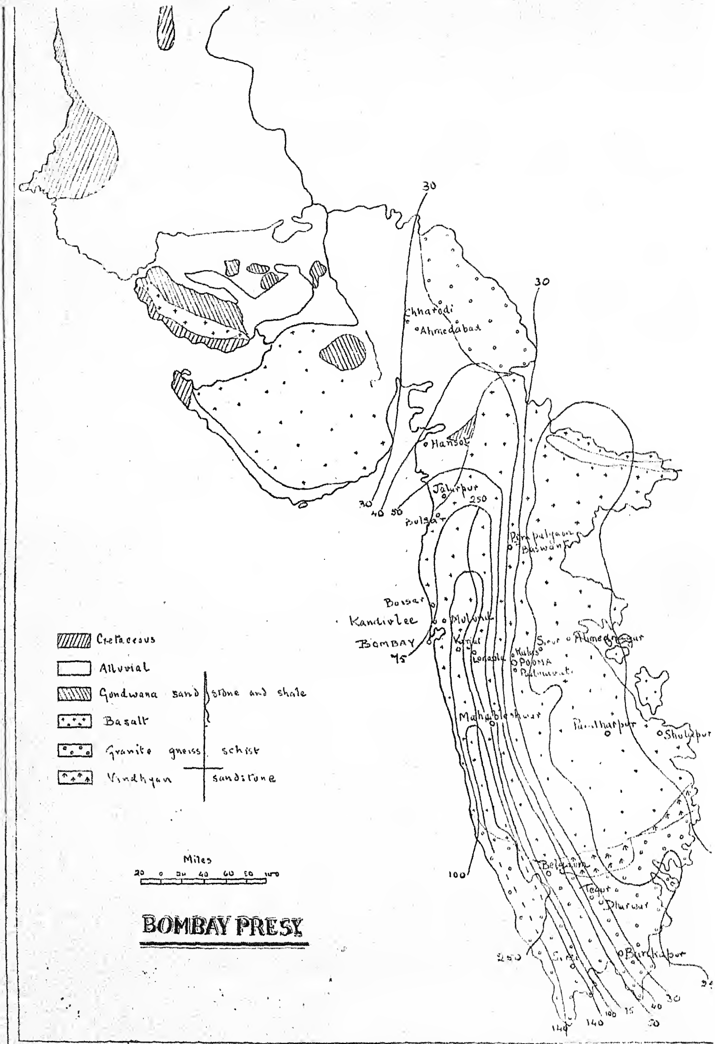

Cretaceous
Alluvial
Gondwana sandstone and shale
Basalt
Granite gneiss schist
Vindhyan sandstone
Miles
BOMBAY PRESY.
Ahmedabad
Hansot
Jalalpur
Bulsar
Boisar
Kandivlee
Mulund
BOMBAY
Karjat
Poona
Mahableshwar
Ahmednagar
Pandharpur
Sholapur
Belgaum
Dharwar
Sirsi

A STUDY OF SOME INDIAN GRASSES AND GRASSLANDS.

BY

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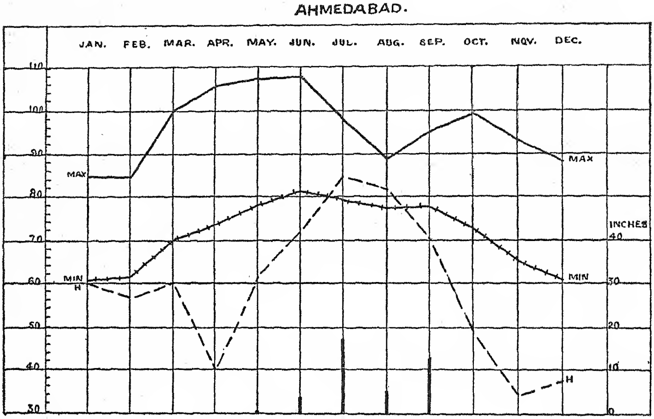
(Received for publication on 5th May 1925.)

I. Introduction.

A glance at the map of the Bombay Presidency (Frontispiece) shows that it is a place where ecological conditions vary greatly. The province excluding Sind is relatively long from north to south, measuring in this direction about 1,100 miles. The greatest breadth is about 250 miles and the average breadth is about 200 miles. The western boundary of the province is the sea and therefore along the coast one gets the customary conditions of high atmospheric humidity and rainfall combined with a moderate daily and annual range of temperature. Since the province is comparatively narrow from west to east, one would expect a gradual change in climatic conditions as one proceeds inland, but such expectation is upset by the appearance of the Western Ghats, a mountainous range whose main ridge runs parallel to the coast. The effect of this ridge is to cause excessive precipitation on the ridge itself and to create a "rain shadow" to leeward of it so that there is a sudden drop of the rainfall on the eastern side. The isohyets on the map clearly indicate this.

The rainfall takes place between June and October, both months included, and is determined by the south-western monsoon. During the months, November to May, both included, there is usually no rain. Occasional showers in December or April are sometimes experienced. The temperature is at its highest in May, the end of dry season, and at its lowest in the months December and January. During the hottest part of the year there also prevail forcible winds from the west which increase evaporation from soil and plant. The year falls naturally into the rainy season, the cold weather, and the hot weather the limits of these periods not varying greatly.



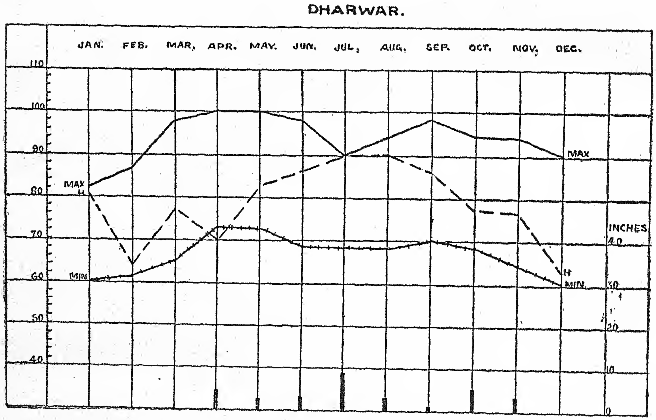
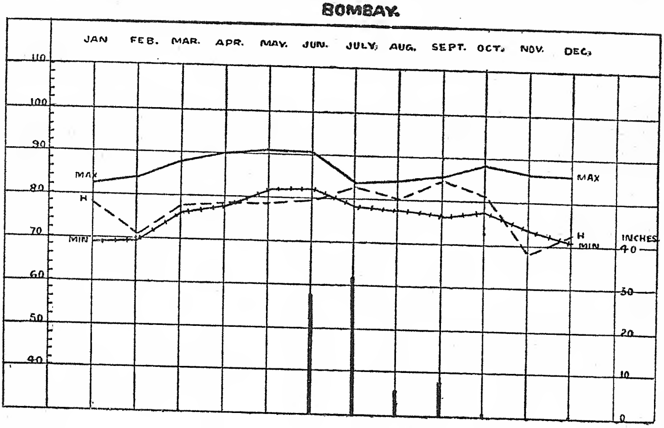
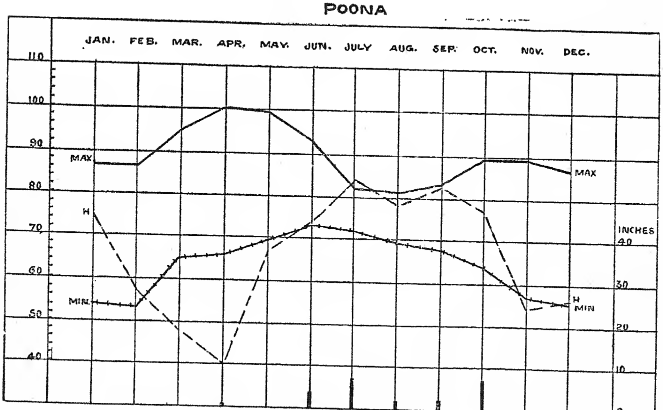


Diagram 1. Graphs showing climatic conditions.

BOMBAY.



POONA



—temperature (max.) ; —temperature (min.) ; .... humidity ; 1 rainfall.

We may consider the rainy season to be June to October, the cold weather, November to February, and the hot weather, March to May.

The underlying rock in the middle part of the presidency is Deccan trap, a volcanic rock of great area and depth. It weathers into a disintegrated form called *murum*, and finally produces soils of varying depth, texture and colour, most of the soils lacking in humus, none of them acid and most of them naturally well drained by the underlying *murum*. The poorer soils have much partially disintegrated rock still present, and large boulders are not uncommon.

Laterite, which is a metamorphic rock and rich in iron compounds, occurs at Mahableshwar, Belgaum, and Ratnagiri on the top of trap rock. In the south of the presidency we find the deep black clayey soil so suitable for cotton cultivation.

In Gujarat, on the north, the underlying rock is probably gneiss and possibly slates and the soil is alluvial and very deep.

We have said sufficient to indicate that climate and soil conditions are variable (Diagram 1) and a corresponding variability in the vegetation is to be expected. We are concerned here with grassland and may say at once that grassland occurs in all the conditions cited.

The long dry season (cold and hot weather) at once rules out the Bombay Presidency as a place for typical grassland in Schimper's sense. *The plentiful grass which exists, consists of (1) perennial grasses whose aerial parts wither and die (and are often burnt) annually, and which persist by their subterranean rhizomes and (2) annual grasses of varying length of life which produce seed about the end of rainy season and then die, their seed lying dormant in the soil during the dry period and germinating at the break of the next rains.

The sudden change of the landscape from khaki to green when the rains break, and the almost equally sudden change from green to khaki when the rains end, are phenomena that delimit the most important part of the Indian year.

A word or two more should be said about this period. In the Bombay Presidency the rain may occur both in light showers and in devastating cloud-bursts. When torrential rains fall there is much run-off and a great deal of erosion occurs especially near the Ghats. The rainfall is sufficient in most places to determine some type of woodland as the climax formation, varying from thorn-forest (mostly *Acacia arabica*) to monsoon forest. Teak (*Tectona grandis*) grows on the slopes of the Western Ghats though to nothing like the size of Burma teak, and in Kanara there is heavy jungle with *Tectona grandis*, *Dalbergia latifolia*, *D. ougeinensis*, *Pterocarpus marsupium*, *Terminalia tomentosa*, *Acacia catechu*, *Lagerstrœmia indica*, *Hardwickia binata*, *Artocarpus integrifolia*, *Mangifera indica*, *Pongamia glabra*, and *Bassia latifolia*. Among the predominating species where the activities of man

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* Schimper, A. F. W. *Plant Geography upon a Physiological basis*, p. 174. "A good grassland climate is then composed of the following elements :—Frequent, even if weak, atmospheric precipitations during the vegetative season, so that the superficial soil kept in a moist condition, and further a moderate degree of heat during the same period."

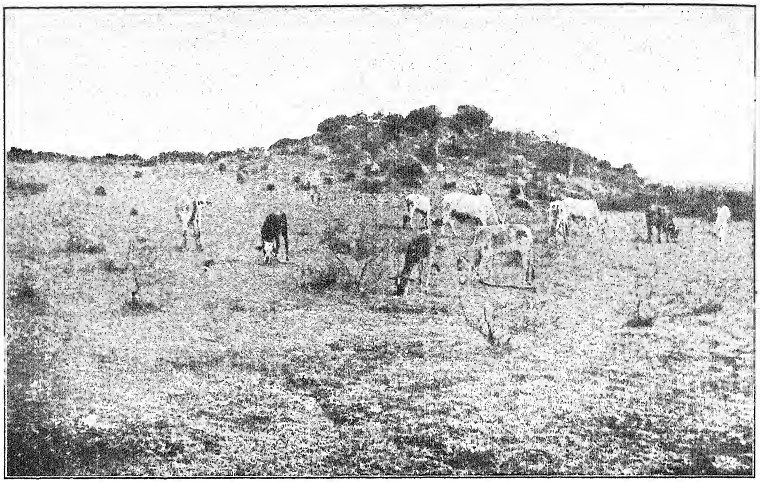


Fig. 1. Boulders at Kalas.

Fig. 2. Surroundings of Kalas plot.

and animals are curtailed, any area in the Bombay Presidency tends to develop its appropriate type of woodland. Cutting, burning, and especially grazing and trampling tend to keep down tree-growth and give the grass its chance as a sub-climax formation.

Variations in grassland, including changes in floristic composition, appear to be conditioned chiefly by soil moisture, this again depending on precipitation, soil depth, texture, and slope. In all the areas studied, succession from xerophytic to mesophytic grasses is indicated. Conditions determining the occurrence of xerophytic species are (1) poor vegetational cover with little power to hold surface water, (2) consequent run-off and erosion, (3) shallow soil and (4) considerable slope. Conditions determining the occurrence of Mesophytic species are (1) dense tufted vegetational cover capable of holding the surface water, (2) deep retentive soil and (3) flat surface. In all conditions the unrestricted growth of grass is itself the best preparation for further improvement since this checks run-off and erosion. Improvement is, therefore, in geometrical progression. The process has been watched in several parts of the Presidency and the following sections deal with special areas :—

II. Grasslands in the Deccan.

Poona itself is situated in the Bombay Deccan and it was natural that this tract, in which the writers' head quarters lay, should get a great part of their attention. Moreover, the practical problem here of producing abundant good grass on poor land with a moderate rainfall was both pressing and interesting. The stations where observations were made were Kalas, Poona, Sirur, Pimpalgaon Basvant, Padmavati, and Pandharpur.

Of these, Kalas is the most important. At Kalas an area of seven acres of the *worst* available soil was leased in 1920 and enclosed. The gradual alteration of the vegetation was studied. In September 1921 and in February 1924 accidental fires occurred in two patches. From September 1923 strips were deliberately burnt, grazed and cut.

The nature of the land is shown in Plate I, also showing the curious flat topped hills of Deccan trap characteristic of the geological area.

Permanent metre quadrats were laid out in six typical places within the fenced plot and the vegetation charted annually in October. Accurate meteorological readings were taken on the spot.

At the end of the hot weather in the grassland of which the Kalas plot is typical, there is very little vegetable cover left (Plate II, fig. 1). Cattle have grazed it down in the preceding rains and fire has destroyed most of the aerial parts. Quadrats laid out outside the fenced area and charted in 1924 show how much absolutely unoccupied space there is in a typical spot ten feet each way.

Wide stretches of land are in this condition. *Acacia arabica*, *Opuntia elatior*, *Zizyphus jujuba*, *Lantana camara*, and *Calatropis gigantea*, all being xerophytic trees

or shrubs, are the only large plants visible. Of herbaceous plants we may discover a few living specimens of *Tridax procumbens*, *Boerhaavia diffusa*, *Evolvulus alsinoides*, and *Tephrosia purpurea*.

After about an inch of rain has fallen the vernal aspect societies make their appearance. These consist of the species *Scilla indica*, *Chlorophytum tuberosum* and *Iphigenia pallida*. These are tuberous monocotyledons which make the most of the early rains and then relapse into dormancy underground for the rest of the year. They are characteristic of stony or rocky places with good drainage. Along with these we find two species of grasses of astonishingly early maturity. These are *Oropetium Thomæum* and *Tripogon Roxburghianus*. Both are characteristic of the shallowest ground with rock showing through. Both are dwarf, *Oropetium* being very diminutive. The rapidity with which they come into flower is extraordinary. Both flower, on the average, within one month after one inch of rain has fallen.

Kyllinga triceps (Cyperaceæ) is equally early. Species of the Commelinaceæ are typical of poor rocky ground. Of these, *Cyanotis tuberosa* and *Commelina Forskalæi* are early. *Cyanotis fasciculata* is much later. The grasses generally make vegetative growth in the early rainy season. Occasionally the annual form of *Andropogon contortus* flowers at this time, and we have observed early inflorescences from the perennial stumps of *Andropogon Monticola*. September and October are the months in which the grasses flower and dry up. According to the seasonal rainfall and the consequent vegetative growth this flowering time may vary a little. A complete list of grass and other species found on the Kalas plot is given in an Appendix.

There is no further change in the vegetation, but the dead aerial parts and the land beneath them receive a scorching in the hot weather, the total effect of which is not yet clearly known. There is, of course, reduction of soil moisture, which is dealt with later.

Effects of enclosure.

The effects of enclosure and the consequent protection of the vegetation from grazing, cutting and burning have been striking. We shall deal with these first briefly and then in detail.

Generally speaking, the main effect of enclosure has been to develop a fair stand of perennial grasses. These are of two kinds, the kinds being determined by edaphic factors.

On the hilly portion the species that have taken hold are *Ischaemum laxum*, *Andropogon Monticola*, and *Andropogon triticeus*, particularly the first two. These have developed dense tussocks (Plate II, fig. 2). All are grasses well known for their occurrence in rocky hilly habitats. Careful search among the boulders of any part of the Deccan reveals their stumps. Ordinarily they never get a chance

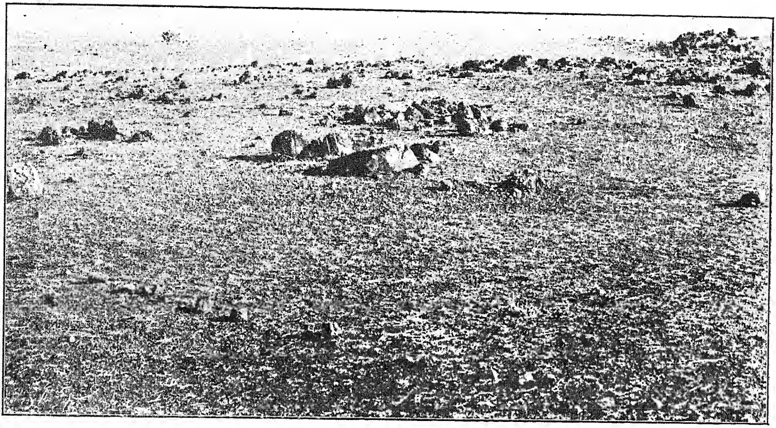


Fig. 1. Kalas plot in hot weather before enclosure.

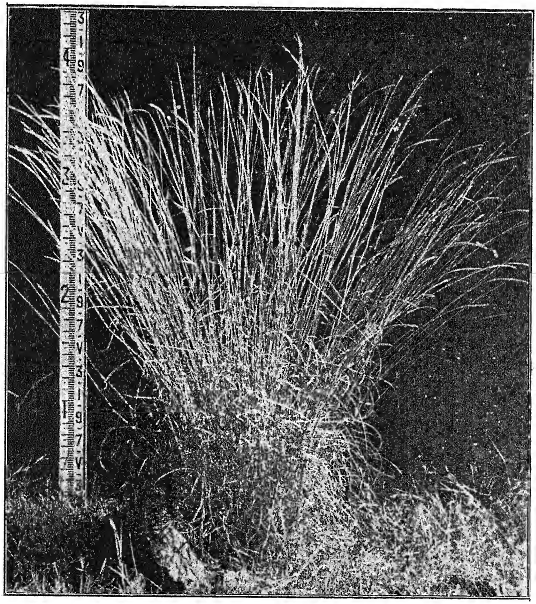


Fig. 2. *Ischaemum laxum.*

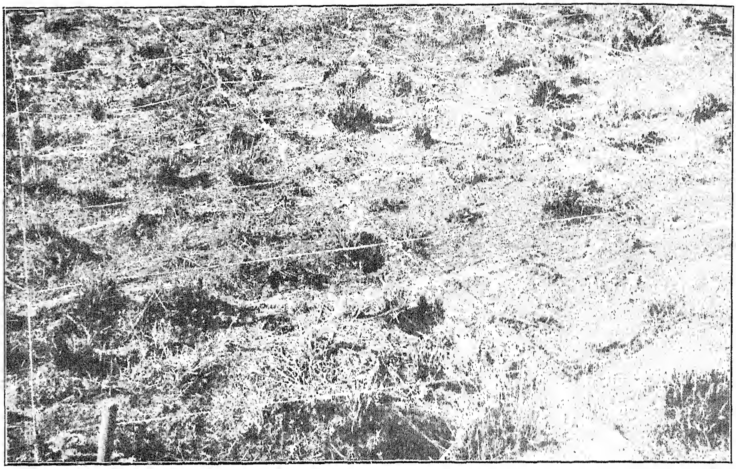


Fig. 1. Part cf the maliciously burned area.

Fig. 2. Dead fibrous grass left unburned.

to develop thick tussocks on account of the perpetual grazing and frequent fires to which they are subject. We seized the opportunity of the accidental fire of 1924 to map out a major quadrat of these stumps so as to show their density per unit of land surface (Plate III, fig. 1). A rough calculation shows that in the five years since we took over the land these stumps have covered about fifty per cent. of the ground in the hill portions and there is no reason why with continued protection they should not entirely cover the hill portions. In one corner of the Kalas plot this has already happened.

In the low lying portion there is a stand of *Andropogon annulatus* and *A. caricosus*. These are growing as a much closer community and hence are not so obviously tussocky as the perennials on the hill portion. There is very little bare space between their stumps.

In addition to these two species the grass *Iseilema laxum* is present in fair amount. There is a fairly sharp line of division between the hill grass flora and the flora of the low-lying portion. It is a perfect example of the dominating influence of edaphic factors. In this case soil moisture and soil texture apparently control the flora. It is worthy of note that the grasses *Andropogon annulatus* and *Andropogon caricosus* are reckoned as the best wild fodder grasses of the Deccan, Gujarat and the Karnatak. Animals prefer these grasses to other species. The cut grass of these species fetches higher prices than that of any other species.

An unforeseen result of the policy of non-interference with the vegetation on the plot was the accumulation of large amount of undecayed vegetable matter. We originally believed that if we did not cut or graze or burn the vegetation it would, under the influence of the weather, turn into humus and so enrich the soil and gradually alter the nature of the flora. To some extent this did happen in the first two years, but when the grass tussocks became large, the dead culms, being full of sclerenchyma, refused to decay, and we got considerable areas between the tussocks covered with undecayed dead straw. It must be remembered that succeeding the ripening of the grasses are seven months of dry weather, so there is no moisture in air or soil to assist in the rotting of the stuff even if it were less fibrous and more likely to rot. It is amazing how it withstands rotting even when the succeeding year's rain falls. So much was this the case that we found that nothing would grow under this natural mulch. In the early rains it prevented the rain from getting at the soil. In the late rains it kept the soil sodden, and at all times it was a physical barrier to light, heat and growth. Plate III, fig. 2 gives some idea of its nature and density.

A similar phenomena occurred in a quadrat on one of the college rides. In 1920 this quadrat as enclosed in order to protect a clump of *Indigofera glandulosa* in which a pink mutation had appeared. The grass at that time was *Andropogon pertusus*. The quadrat was protected by stout posts and wire netting so that no grazing took place and the grass grew to its full height and flower. No observations were made in 1921. In 1922 the *Andropogon pertusus* had well nigh disappeared and the domi-

nant grasses were *Andropogon caricosus* and *Anthistiria ciliata*. This mass of dead grass remained on the ground and in the rains of 1923 there was no growth of any grass due to this mass of dead stuff. In March 1924 the position was as shown in the quadrat given in Fig. 1. *Lagasca mollis* had got hold of one corner, there

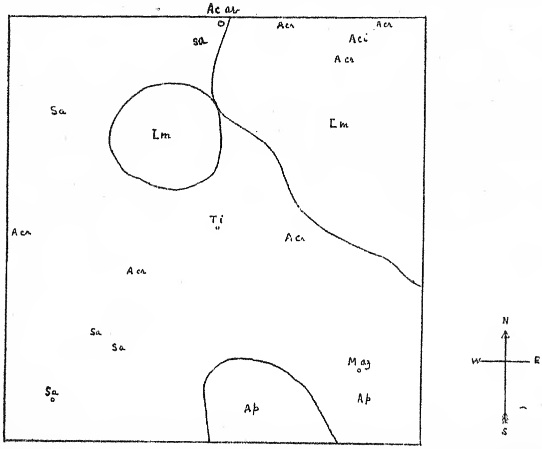


Fig. 1.

QUADRAT C.

Enclosed 1920.

Charted 4th March 1924.

Ac ar	*Acacia arabica*	Willd.
A cr	*Andropogon caricosus*	Linn.
Sa	*Sonchus arvensis*	"
Lm	*Lagasca mollis*	Cav.
Aci	*Anthistiria ciliata*	Linn. f.
Ti	*Tamarindus indica*	"
M az	*Melia Azadirachta*	"
Ap	*Andropogon pertusus*	Willd.

o indicates individual plant.

was some of the rudera' *Sonchus arvensis*, a little *Andropogon pertusus*, and some *Andropogon caricosus* tried to put out a little foliage. The *Lagasca mollis* had spread over two-thirds of the plot by April 25 (Fig. 2). On June 11 the position was

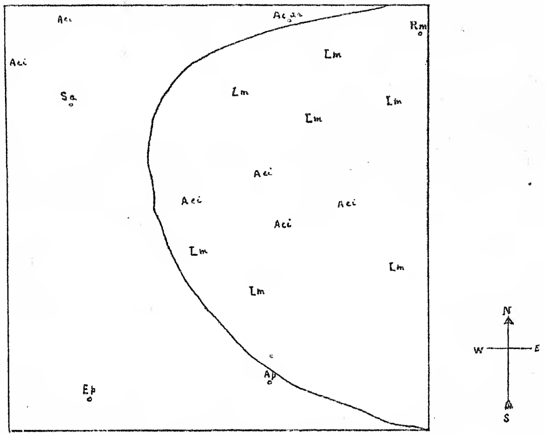


Fig. 2.

QUADRAT C.

Enclosed 1920.

Charted 25th April 1924.

A ci	. . . .	*Anthistiria ciliata*	Linn. f.
Sa	. . . .	*Sonchus arvensis*	,,
Ep	. . . .	*Euphorbia pilulifera*	L.
Ap	. . . .	*Andropogon pertusus*	Willd.
Lm	. . . .	*Lagasca mollis*	Cav.
Ac ar	. . . .	*Acacia arabica*	Willd.
Rm	. . . .	*Rhynchosia minima*	DC.

o indicates individual plant.

much the same, and by September 22nd only a small corner was unoccupied. The quadrat (Fig. 3) is now a mass of dead *Lagasca mollis*, and it will be interesting

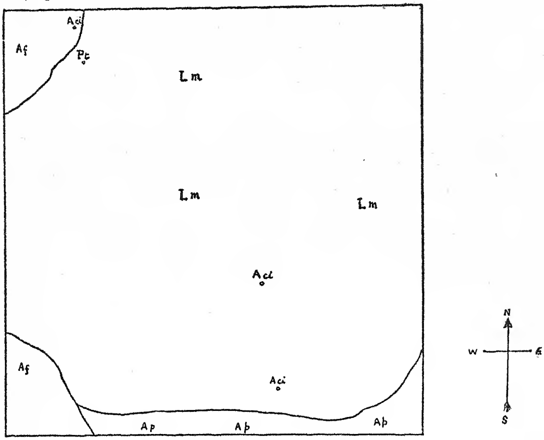


Fig. 3.

QUADRAT C.

Enclosed 1920.

Charted 22nd September 1924.

A ci	*Anthistiria ciliata*	Linn. f.
Pt	*Phaseolus trilobus*	Ait.
Af	*Andropogon foveolatus*	Del.
Lm	*Lagasca mollis*	Cav.
Ap	*Andropogon pertusus*	Willd.

o indicates individual plant.

to see what happens next. The growth in the dry season is explained by the fact that water occasionally leaked into the plot from a near-by water channel.

To test the effect of this natural mulch on germination we tried the following experiment :—

We selected two places fairly close to each other, one bare and the other covered with the debris of old grass, and sowed seed of *A. purpureo-sericeus* in both places (*i.e.*, on the bare soil and under the mulch). In both places the seed germinated,

but after fifteen days the seedlings in the bare patch were healthy while those under the mulch were very sickly and eventually few survived.

Additional proof is afforded by the fact that wherever this rubbish was found one could detect nothing growing underneath it, or through it.

It was on this account that we finally decided to try the effect of burning in 1923-24. This was done according to the following plan, comparing burning at two seasons with cutting, grazing and check plots.

As we have already mentioned, the fire of February 1924 somewhat upset our programme, but all the same the main lines of the experiment were carried out. The results so far as they have appeared are as follows :—

(*a*) *Immediate effects*. In the low-lying portion *Iseilema laxum*, *Andropogon annulatus* and *A. caricosus* began to sprout from the burned stumps ten days after the fire, and made rapid progress thereafter. Some of the stumps of *A. a nulatus* actually flowered within six weeks of the fire. The hot weather of April killed the new shoots and foliage. On the hilly portion the only grass to sprout was *Andropogon triticeus*, which gave new foliage within a fortnight. This also died in the heat of April. Of the non-graminaceous plants, *Evolvulus alsinoides*, *Euphorbia coccinea*, *Tridax procumbens* and *Vicoa auriculata* rapidly put forth new foliage.

(*b*) *Later effects*. There was early growth at the break of the rains and a greater development of foliage, than in the unburnt portion. Germination of seeds of all kinds in the spaces in the burnt area was more dense than in other places.

On the hilly portion between the tussocks of perennial grasses remains much of the original type of vegetation of which *Andropogon contortus* is the main component. In addition, we find *Aristida funiculata* and *Aristida Adscenscionis* common, along with the plants mentioned above as surviving the burning.

In certain parts of the hill portion there is a good deal of soil that is still bare in the hot weather. In the rains the vernal plants, the non-graminaceous ruderals, the smaller form of *Andropogon contortus*, and masses of *Glossocardia linearifolia* occupy these spaces, but after the rains the land is still bare. Such patches offer easy run-off for the early rains and may give opportunity for erosion. It seems to us that regeneration of these very poor soils is bound to be a slow business and to depend entirely on the gradual spread of the perennial tussock grasses of which the old dead culms, if any remain at the end of the rainy season, must be prevented from forming a mulch on the land. Once established, however, it is plain that this type of grassland will tolerate great drought, grazing, cutting and fires. The essential point is that one must allow several years of protection for its full establishment. As these stumps grow in diameter somewhat slowly and as propagation by seed does not seem to be very efficient, we tried the increase of these stumps by breaking up

one or two old ones and planting the small stumps in July 1924. The very poor rains of that month tested their resisting powers severely but in spite of this the stumps came through all right and were alive and growing in October. It is worth while, therefore, increasing the number of stumps by this method and so rapidly closing up the gaps between the perennial tussocks.

The grass community of the *Andropogon annulatus* type in the better low-lying portion develops quickly and densely. In its case all one has to do is to arrange for a long rest at the beginning of the treatment of such land and thereafter by rotational grazing and cutting see that the stumps are not exhausted and killed out and the poor grasses let in again. We shall return to this question later on when discussing the management of grasslands.

The intensive study of the changes in vegetation made upon the permanent quadrats gave several important indications. In 1920 six single quadrats were charted. In 1921 a denuded (scraped) and a burned quadrat were charted beside four of these, and a scraped quadrat only beside one other. The quadrat which had no comparison quadrat was on very rocky ground. The following table shows briefly the changes which have occurred in total plants and in number of species.

Change in total number of plants per quadrat.

	1920	1921	1922	1923	1924
Group I					
Original	318	771	..	1,011	1,049
Scraped	..	127	..	810	722
Burned	..	547	..	1,547	1,139
Group II					
Original	177	1,360	..	..	1,939
Scraped	..	574	..	..	809
Burned	..	472	..	..	1,728
Group III					
Original	22	593	..	534	497
Group IV					
Original	490	691	..	901	821
Scraped	..	279	..	1,621	553
Burned	..	659	..	1,142	826
Group V					
Original	686	892	..	1,425	1,784
Scraped	..	406	..	1,508	1,266
Burned	..	659	..	1,744	1,972
Group VI					
Original	401	397	..	..	656
Scraped	..	218	..	..	590

The entire lack of data in 1922 is due to a change in research personnel. The absence of figures for 1923 in Groups II and VI is due to very late mapping.

The general conclusions reached from the above table are these :—

(1) *Original quadrats.* One year's enclosure markedly increased the total number of plants. This is probably partly because they were undisturbed in their seeding and also because they were not attacked during germination and in the seedling stage. The 1924 results show a markedly denser population than in 1920.

(2) *Scraped quadrats.* Scraping reduces the number of individual plants except in Group II. Recovery is rapid, though in 1924 none of the scraped quadrats have quite as dense a population as the original quadrats. They are, however, a year behind the original quadrats.

(3) *Burned quadrats.* There is no reduction of species except in Group VI. Burning, therefore, so far as number of plants is concerned left the quadrat practically at the stage which it had reached in its first season's enclosure. The final figures of burned quadrats in 1924 agree approximately with those of the original quadrats.

(4) *All quadrats.* Year 1923 seems to have been more favourable to density of population than 1924. This was probably due to the fact that in 1924 really effective rain was delayed till August. Probably many seedlings germinated with the light showers of June and July but died in the dry sunny intervals.

General conclusion. The effectiveness of enclosure in increasing the density of plant population in this grass land is clearly demonstrated.

Change in number of species per quadrat.

	1920	1921	1922	1923	1924
Group I					
Original	7	7	..	21	25
Scraped	..	11	..	33	34
Burned	..	9	..	23	32
Group II					
Original	11	9	..	..	19
Scraped	..	19	..	.	21
Burned	..	12	..	..	23
Group III					
Original	3	13	..	9	9

Change in number of species per quadrat.

	1920	1921	1922	1923	1924
Group IV					
Original	23	19	..	17	31
Scraped	..	19	..	12	22
Burned	..	10	..	16	32
Group V					
Original	17	17	..	21	22
Scraped	..	20	..	22	25
Burned	..	12	..	24	24
Group VI					
Original	11	13	..	..	16
Scraped	..	9	..	..	19

The general conclusions reached from the above table are these :—On the whole there has been an increase in the number of species in the quadrats though this increase is not a steady rise. The scraped quadrats probably gave an excellent denuded area offered to immediate colonization by all sorts of seeds and hence the large number of species in them in their first year. Burning has had no effect on reduction or increase of species.

Succession as revealed by the change of species in these quadrats has taken the following course. In the dry hilly area with shallow soil and much rock the tendency is for the soil to bear, in the first stage, species of the *Commelinaceæ*, then the poor grasses *Oropetium Thomæum, Tripogon Roxburghianus* and *Gracilea Royleana*. The next stage is the establishment of *Aristida* species (*redacta, funiculata,* and *Adscenscionis*) along with the annual form of *Andropogon contortus*. The next stage is the growth of the perennial form of *Andropogon contortus*. The unenclosed land never gets beyond this stage and most of it is in the *Aristida* stage with scattered patches of all stages right back to the sheer rock. Weeds and ruderals occupy much of the ground on which grass species have not established themselves, *e.g., Glossocardia linearifolia, Spermacoce stricta* and *Zornia diphylla* form close societies on poor ground. *Vicoa auriculata* and *Leucas longifolia* occur in groups. *Striga densiflora* is found in poor shallow soil as a parasite on *Andropogon contortus*. *Sopubia delphinifolia* occurs in the moister part as a parasite on *Andropogon annulatus, Andropogon caricosus* and *Iseilema Wightii.*

Progress beyond this condition (in which *Andropogon contortus* and *Aristida* species dominate, with remnants of preceding stages interspersed) occurs only after enclosure. Such progress has taken two distinct lines. On the hilly slopes the perennial tussock grasses *Andropogon Monticola, Andropogon triticeus* and *Ischæmum laxum* develop strongly, gradually ousting *Andropogon contortus* and *Aristida* species.

On the lower parts where there is a deeper soil and more soil moisture, *Andropogon annulatus*, *Andropogon caricosus* and *Iseilema laxum* form a dense stand, entirely ousting the vegetation of the previous stage. Where water tends to lie there is inevitable development of Cyperaceæ and swamp weeds.

Other stations in the Deccan.

It will be suitable to deal collectively with results obtained at the other Deccan stations (Sirur, Pimpalgaon Basvant, Padmavati, Pandharpur and Poona). These places generally resemble Kalas in climate an soil. In certain places there is more or less slope, along with which goes inevitable run-off, erosion, and denudation. Wherever cattle have free access the vegetation is similar—stunted, weedy and sparse. Where cattle are entirely excluded there is, even on poor soil, a fine stand of grass. The most striking example of this is at a village about nineteen miles from Nasik called Pimpalgaon Basvant, where there is a common land managed by the villagers for their mutual benefit. The soil is poor and shallow. The rainfall is 30 inches annually. From time beyond the memory of the present inhabitants the same system has been followed. A total area of 800 acres is set aside and cattle kept off by means of watchmen. The grass on this at the end of the season is divided out among the villagers according to their assessment. The villagers say that there is no difficulty in working the system, which they control by means of a *panchayat* or committee. The grass is cut and taken away after it flowers, and then grazing is permitted.

The area which is thus treated is visible at the flowering season miles away in contrast to the surrounding land, on account of the massed golden inflorescence of *Andropogon Monticola*. This grass has established itself as the dominant grass over the greater part of the area. Along with it in certain portions appear great masses of *Andropogon purpureo-sericeus*, a grass that we have met rarely elsewhere. *Ischaemum rugosum*, which we shall mention as a denizen of wetter parts at Chharodi, here appears also in similar places : *Andropogon pumilus* and *Ischæmum sulcatum* made a good bottom growth. *Andropogon contortus* is present but markedly subordinate, and, as we have already mentioned, is found only where the soil has been eroded by water and the land is more stony and gravelly. A little *Aristida redacta* is present.

The moment one gets out of this protected area one is in another type of vegetation altogether. The following species were found in the unprotected area, close to the protected part :—*Iseilema Wightii, Aristida redacta, Panicum Isachne, Tripogon Jacquemontii, Panicum javanicum, Ischæmum pilosum, Justicia diffusa, Pulicaria Wightiana*. This area, of course, was grazed and the vegetation short.

Here we have a very notable experiment in the enclosure of grassland and the prevention of grazing till after flowering and cutting. We do not know how long this experiment has gone on, but we may assume that it has continued for the last

thirty years at least. The result is a fine stand of good perennial grasses with at least two good grasses as bottom growth, and with *Andropogon contortus* in a very subordinate position on the eroded soil only.

On better soil where any degree of protection is practised there is a change from *Andropogon contortus* to *Andropogon pertusus* and finally to *Andropogon caricosus* and *Andropogon annulatus*. These two last named grasses usually occur mixed and are collectively regarded as the best grasses in the presidency being called *marvel* in Marathi, *zinzva* in Gujarati and *marol* in Kanarese. The dominance of *Andropogon pertusus* is marked in certain parts of the college farm, grazed moderately by cattle, while the dominance of *Andropogon annulatus* and *Andropogon caricosus* is complete on both deep and shallow soils where grazing is entirely absent.

In Deccan conditions there appear to be two kinds of sub-climax grassland, determined and defined by soil water-content :—(1) Grassland consisting of grasses such as those on the hilly area in the Kalas plot (*Andropogon contortus*, *Andropogon Monticola*, *Andropogon triticeus*, and *Ischœmum laxum*). This is typical of all mountainous and shallow soils. Pimpalgaon Basvant represents it at its best. (2) Grassland consisting mainly of *Andropogon annulatus*, *Andropogon caricosus* and *Iseilema laxum* found on soils deep and rich enough to have a high water-content.

The actual differences in soil water-content between these two types are shown in the following table.

Total soil moisture from the soil sample taken under the different species at the end of the hot season in 1923 and 1924.

Nature of soil	Species	1923		Mean	1924		Mean
		Sample No. 1	Sample No. 2		Sample No. 1	Sample No. 2	
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1. Hilly and poor soil; depth varying from 3″ to 6″	*Andropogon Monticola.*	3·13	3·68	3·40	6·7	6·6	6·65
2. Ditto . .	*Ischaemum laxum*	3·02	3·54	3·37	6·2	7·8	7·00
3. Deep and retentive soil; depth varying from 12″ to 18″.	*Iseilema laxum* .	8·14	8·84	8·49	13·9	12·6	13·25

These two edaphic associations occur side by side within the same climatic conditions and may alternate within short distances.

III. Grasslands in Gujarat.

Geographically Gujarat includes the north-western part of the Bombay Presidency proper. Typical Gujarat grassland differs from typically Deccan grassland

in a variety of ways. As an example of such typical Gujarat grassland, we may select the Government Cattle Breeding Farm at Chharodi. (Frontispiece.) The average rainfall is 28·83 inches, practically the same as the Poona rainfall, but there are differences in elevation, temperature, soil, and physiographic conformation.

Poona is 1,850 feet above sea-level, while Chharodi is 107 feet above sea-level.

Both Poona and Chharodi are about the same distance from the sea, but Poona lies on the leeward side of the Western Ghats.

The soil is clay loam of whitish grey colour varying from one to several feet deep. In many places it is mixed with very fine sand. The sub-soil is yellowish white of a loose texture mixed with lime nodules in some places; on the whole the soil is imperfectly drained.

The land is flat or with very slight slopes.

The trees present on the land are *Acacia arabica, Butea frondosa, Azadirachta indica* and *Zizyphus jujuba.* The presence of *Butea frondosa* is an indication of changed conditions, and it is the dominant tree form. If left to itself there is little doubt that the land would become *Butea frondosa* forest.

We have a fairly complete record of the grass vegetation from 1919 to 1924 both from permanent quadrats and from observations on the whole area of 2,000 acres. When the land was taken over by our department in 1919, it was suffering in many places from the grazing and trampling of cattle which had roamed over it without restriction. The Chharodi grassland responded rapidly to either good or bad treatment. The fine grasses *Andropogon annulatus, Apluda varia, Polytoca barbata* and *Iseilema Wightii* readily establish themselves if unfavourable conditions are removed, especially if the soil water condition improves. In several quadrats the process was clearly visible. The retrograde process was also demonstrated in other quadrats where the vegetation was again subjected to excessive grazing and trampling after a stand of good grasses had been reached. *Chloris pallida, Chloris virgata, Setaria glauca, Indigofera cordifolia,* and *Indigofera linifolia* are characteristic of such bad conditions.

Andropogon contortus is not so prominent here as in the Deccan, but the *Aristida* species are very markedly present in the poor land. The Eragrostidæ are common along all foot-paths.

An area on medium black clay loam was cut year after year and not grazed. Here as at Pimpalgaon Basvant in the Deccan, there had developed an excellent stand of good grasses, the vegetation remaining constant from year to year. The dominant species in this part were *Andropogon annulatus, Polytoca barbata* and *Ischæmum rugosum.* The last named species is definitely hygrophytic, being found wherever water tends to accumulate during the rains. Very marshy conditions are indicated by *Eragrostis cynosuroides* and, if there is salt as well, then we find *Scirpus*

maritimus. These species disappear with the sweetening and draining of the land.

The problem of halophytic grassland was presented to us in acute form at Hansot.

In March 1924 the Collector of Broach asked us to examine certain reclaimed land in the neighbourhood of the village of Hansot and to advise as to the improvement of the grass in it. This place we visited in May 1924 and again in September 1924.

It is ecologically a most interesting spot. It lies at the mouth of the Nerbudda in ground that has been once a part of that very mutable delta. The water that washes it is salt, and the general landscape is a wilderness of muddy flats decorated with the bright green of certain halophytic vegetation. In the year 1900 a huge bund was built as a famine work, enclosing 2,500 acres of this land. The nature of the bund and of the surrounding country is shown in Plate IV, fig. 1.

Of the 2,500 acres within the bund, 1,100 are now under cultivation, leaving 1,400 acres for grazing. On this approximately 5,000 cattle from the neighbouring villages are said to graze. Of the 1,400 acres a certain amount is the old bed of the river, a certain amount is dry creek, and the vegetation varies markedly according to the physical and chemical nature of the soil. On our May visit we took certain soil samples from land characterized by the remnants of different kinds of plants. As it was the hot weather we could recognize only a few species but these were enough for our purpose, and the analyses given in table below indicate how dry the soil had become and how great a difference there was between the reclaimed and the unreclaimed land. The typical salt indicator was *Scirpus maritimus* whose rhizomes at this time were strewn about the surface. In addition, in areas of less salt were *Cressa cretica* and *Coldenia procumbens*. In areas really reclaimed we were told that *Andropogon annulatus* flourished.

We recommended a control of the number of cattle grazed and a system of fencing and rotational grazing. In addition we pointed that there was only one outlet for the water, and that within the bund water must in many places lie for considerable periods during the rains, a condition that did not make either for the good growth of grass or for the quickest removal of the surface salts.

In the better land there were also well-grown trees of *Acacia arabica*.

In September 1924 we revisited the place which had 31·20 inches of rain that monsoon. At the time of our visit there was still a lot of water lying in the fields and within the bund at the Hansot end particularly there was considerable depth of water. Our observations on the vegetation were then as follows.

Riding along the bund one observed that in the mud outside the bund *Scirpus maritimus* and *Cynodon dactylon* were the only visible vegetation. There was no vegetation on the outer face of the bund said to be due to the additional salt accumulated there due to the yearly repair of the outer face from soil brought from out-

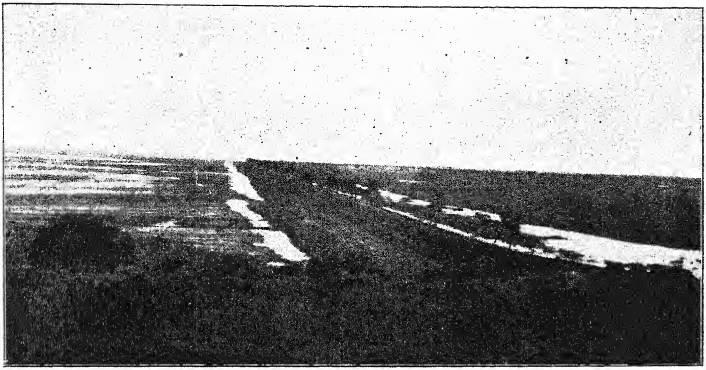


Fig. 1. The Hansot Bund; reclaimed land to the right.

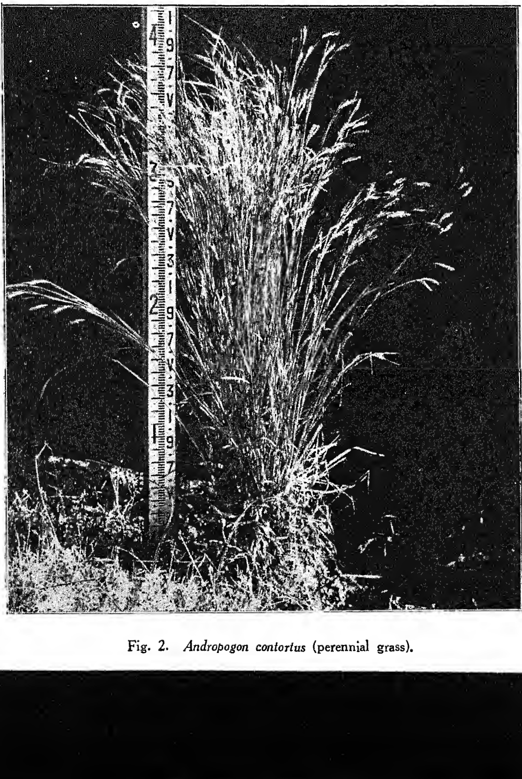


Fig. 2. *Andropogon contortus* (perennial grass).

side the bund. The inner face of the bund had scattered growth of *Chloris virgata.* The renewal earth in the case of the inner face is taken from inside the bund.

Near the village of Hansot *Scirpus maritimus* was dominant. As one approached the village of Ganpatpura, *Scirpus maritimus* began to be less conspicuous and *Sporobolus coromandellianus, Chloris barbata, Eragrostis pilosa, Panicum colonum, Panicum ramosum*, and *Aeschynomene indica* appeared. *Cassia pumilia* was common in wettish soil, and there were rare plants of *Andropogon annulatus*. *Acacia arabica* was growing well, and some *Zizyphus jujuba.* We were told that near Ganpatpura the cultivators were bringing some portions of land with this flora under cotton and *jowar* (*Andropogon Sorghum*). The treatment is that the land is ploughed and left so for two or three years, to allow the rain water to penetrate the lower layers and wash out the salt, and cotton then grows satisfactorily.

Farther back from the influence of the salt in the village of Sajot we made certain other observations also, both in May and September. The growth of *babul* (*Acacia arabica*) trees in this part was excellent, the land was of the analysis shown in column 1 of the Table on p. 20 and was said to have *Andropogon annulatus* on it during the rains. Not far off from this, an acre of land was roughly fenced in August 1924 and we visited it in September. The surrounding land was characterized at that time by *Ischæmum rugosum* in the wetter parts and *Polytoca barbata* in the drier parts, just as in one of the sections of the Chharodi farm. Intermingling with these was the five-foot tall *Alysicarpus longifolius*, and there was some *Anthistiria ciliata.*

Within the fenced acre the vegetation was shorter. It consisted largely of *Ischæmum rugosum*, with some *Anthistiria ciliata* and *Alysicarpus longifolius.* In addition we found *Andropogon annulatus, Chloris pallida, Polytoca barbata, Panicum ramosum, Perotis latifolia, Aristida Adscenscionis, Setaria glauca, Eleusine ægyptiaca, Digitaria sanguinalis, Crotalaria linifolia, Justicia simplex* and *Melochia corchorifolia.*

We decided to cut half of this fenced acre and leave the other half to seed to determine the changes, if any, that complete protection would yield as against cutting in flower.

We have here a well marked succession from wet salt land to dry arable land. There is no doubt of the success of the reclamation. The loss of salt, however, has been very uneven and hence we get all stages in the succession still visible. These are markedly three, namely, (1) The wet salt vegetation consisting of *Scirpus maritimus, Zoysia pungens*, and *Aeluropus villosus*, along with *Cressa cretica* and *Coldenia procumbens* when parts of such areas get dried in the hot weather, (2) the transition grassland with some of these halophytic species still visible but with a mixed grass and leguminous pasture of poor grasses such as *Chloris* and *Eragrostis*; (3) the same stage as in the Chharodi cut area, *Ischæmum rugosum* and *Polytoca barbata* dominant with *Andropogon annulatus* subordinate.

Analysis of and species found in the 4 soil samples from Hansot Mahal, Broach District

	No. 1 Survey No. 122, near the bund at Sajot	No. 2 Survey No. 104, outside the bund at Hansot (Salt land)	No. 3 Survey No. 13, creek land	No. 4 Survey No. 102, bed of the creek.
	Per cent.	Per cent.	Per cent.	Per cent.
Moisture	4·940	4·520	3·0000	2·3500
Total soluble solids	0·058	6·370	0·1120	0·0840
Containing—				
Calcium carbonate	..	0·051	0·0130	..
Calcium sulphate	..	0·324	*Nil*	..
Calcium chloride	..	0·399	*Nil*	..
Magnesium carbonate	..	*Nil*	0·0023	..
Magnesium chloride	..	0·646	*Nil*	..
Sodium carbonate	*Nil*	*Nil*	*Nil*	0·0232
Sodium bicarbonate	..	*Nil*	0·0287	..
Sodium chloride	..	4·450	0·0505	..
Species found	*Andropogon annulatus, Cynodon dactylon*	No vegetation	*Scirpus maritimus*	*Cressa cretica, Coldenia procumbens*

Analysis of Bet grass (Scirpus maritimus) *from Broach District Salt lands.*

	Per cent.
Moisture	15·20
Ether extract	1·55
Albuminoids*	4·62
Digestible carbohydrates	47·63
Woody fibre	18·30
Ash†	12·70

The above remarks are confirmed by observations made elsewhere at other times by ourselves and others. We may mention two cases.

In 1909, Dr. H. H. Mann investigated some land partially reclaimed from the sea for the cultivation of rice at the village of Chichni near Boisar on the same coast as Hansot but further south. Here the land is very stiff and heavy. After the building of a bund, the salt is not washed out sufficiently for rice cultivation until after at least ten years, with an annual rainfall of 70 inches.

In partially reclaimed land the first plant to appear is *Aeluropus villosus*. This disappears as the land gets less salt. *Scirpus maritimus* appears a little later and remains until after the land is able to grow salt rice. It is very difficult to eradicate.

* Containing nitrogen . . . . . 0·74
† Containing sand . . . . . 3·95

Cressa cretica, *Ammania baccifera* and *Heliotropium supinum* were th[illegible] plants found.

The other case was also on the same coast at the village of Bassein. Here there were some salt patches still in sweet rice fields. These were investigated in 1914. The characteristic plant was again *Scirpus maritimus*. Along with it were *Diplachne fusca*, *Sesbania aculeata* and *Andropogon halepensis*. Here the bunds between the fields carried an excellent grass cover containing excellent species of *Ischæmum* *Andropogon* and *Apluda*.

It is plain that these salt lands can be turned into excellent grasslands. The heavy annual rainfall means lush growth when the land is good, as will be indicated in the later chapter dealing with land at Kandivlee also on the same coast, but removed from the influence of salt.

IV. Grasslands near Bombay.

The study of such coastal grassland leads us naturally to the consideration of coastal lands a little further south, in a heavier rainfall area, and with soil no longer salt. Such is found at Kandivlee, a small station on the Bombay, Baroda and Central India Railway about 20 miles north of Bombay. There is an area of 500 acres here in charge of a charitable organization, the Bombay Gowrakshak Mandali, whose object is the protection and care of cattle. We have been able to observe the grassland from September 1922, the date when the Bombay Agricultural Department began actively to co-operate with the Mandali. The grass area was much interrupted by the growth of *Lantana camara*, *Carissa carandas* and many trees of *Borassus flabellifer*. The main grasses were *Ischæmum aristatum*, *Anthistiria ciliata*, and *Anthistiria hispida*. *Ischæmum aristatum* grew on the lower lying portions and the *Anthistiria* species on the higher ground. In a heavy rainfall year the *Ischæmum* tends to increase. The rainfall is normally heavy, averaging 90 inches. Monsoon forest would be the normal climax and this we find when we get into the forest reserves or wherever the land is efficiently protected from grazing. The tract in which these conditions hold may be considered to include the whole area between the Ghats and the sea. The soil at Kandivlee is well drained and is itself a rich loam. Hence with the high rainfall and the humidity due to the proximity of the sea the actual mass of grass vegetation produced is tremendous. An experimental cutting gave 30,000 lb. green grass per acre. *Andropogon contortus*, being definitely xerophytic, is absent. In addition to the species already mentioned there are present in quantity *Coix Lachryma-jobi*, and *Pollinia fimbriata*. Many of the smaller grasses are present and are visible in the early rains before the taller species develop their height. Such smaller species are *Panicum colonum*, *Digitaria sanguinalis*, *Paspalum scrobiculatum*, *Panicum trypheron*, *Isachne australis*, and *Setaria glauca*. There is also a very miscellaneous non-grass flora consisting among others of *Cardiospermum Halicacabum*, *Fimbristylis monostachya*, *Lippia nodiflora*,

Phyllanthus simplex, *Euphorbia hypericifolia*, *Cyperus Iria* and the parasites *Rhamphicarpa longifolia* (replacing, *Sopubia* and *Striga* of the Deccan). Two unusually interesting plants were *Neptunia triquetra*, which is almost as sensitive as *Mimosa pudica*, and *Flemingia tuberosa*, a tuberous member of the Leguminosæ.

Such non-grass plants increase where over-grazing and trampling occur. This was clearly visible at Mulund not far from Kandivlee. In this badly treated area the tall productive grasses had nearly disappeared and only the smaller ones were present.

V. Grasslands in the Southern Maratha Country.

The part known as the Southern Maratha Country includes the districts of Belgaum, Dharwar and Bijapur. The rainfall in the headquarter towns (of the same name) in these districts are: Belgaum 50·13 inches, Dharwar 32·00 inches, and Bijapur 20·90 inches. Their elevations are 2,260, 2,580, and 1,950 feet above sea-level respectively.

Their temperatures at four typical seasons of the year are as follows :—

—	Belgaum		Dharwar		Bijapur	
	Mean Maximum	Mean Minimum	Mean Maximum	Mean Minimum	Mean Maximum	Mean Minimum
	F.	F.	F.	F.	F.	F.
March . .	93·5	62·2	89	71	97·7	69·3
June . .	83·2	68·3	88	74	94·2	71·1
September .	79·9	66·2	81	71	85·9	69·9
December .	81·1	57·2	79	64	83·5	55·6

It will be noted that Bijapur gets fairly hot, while Dharwar has an equable climate all the year. Belgaum is more or less intermediate.

The general nature of the seasons may be judged by the fact that cotton is sown in the Southern Maratha Country in the middle of August and harvested in February and March, while in Gujarat it is sown in June and harvested in February and March. In Khandesh, on the other hand, it is sown in June and harvested in November and December. The season in the Southern Maratha Country is, therefore, on the whole late.

The grass country is large in amount and often bounded by low hills covered with jungle in which panther and pig abound. The presence and depredations of pig have caused large areas to go out of cultivation and to revert to grass.

In the Southern Maratha Country, the Bombay Department of Agriculture has two cattle-breeding centres, one at Tegur and the other at Bankapur, both in the Dharwar District. We shall consider both these places as to their grass vegetation.

Bankapur. Our cattle breeding farm here is within the walls of an old fort. This fort after many vicissitudes passed into British hands in 1802. Its present condition is that the outer ramparts exist practically all the way round. They have a granite core but are covered with earth on which grass and shrubs grow. The bastions are easily recognizable and in some cases are in good preservation. The gateways are rather broken-down and the gates do not exist. An inner line of ramparts is still visible, but only as a low mound, and also an inner ditch which is not continuous. Of buildings within the fort there remain a very fine Jain temple, a smaller Jain temple, a mosque, an old granary and a powder magazine. The rest of the ground is under grass.

Rainfall is 26 inches, again similar to that of Poona. Elevation is about 2,600 ft., soil is loam with much masonry rubble, and the drainage is good.

We have observed the grassland of this fort since 1920 when the place was taken over by us. *Andropogon contortus* was then dominant everywhere. *Setaria glauca* and *Eragrostis* species were common. *Setaria intermedia* was specially found under tamarind trees. Along the top of the ramparts was *Tripogon Jacquemontii.*

After four years of reasonable grazing, rotated with cutting, there was a marked change. *Andropogon contortus* is now dominant only in one part isolated between the outer and inner rampart on the south side of the fort. On the north-west and east *Apluda varia* is dominant, and in the centre *Ischæmum laxum* is dominant. Badly trodden ground produces a mixed vegetation of *Chloris virgata, Cynodon dactylon, Andropogon pertusus, Tripogon Jacquemontii* and *Setaria intermedia.* The tamarind trees had under them *Achyranthes aspera,* with *Setaria intermedia* in close contact. *Anthistiria ciliata* is invading from the south gate.

A most significant fact was that an area in an *Andropogon contortus* consociation, accidentally denuded by having *murum* (disintegrated trap) stacked on it, was repopulated next rains not by *Andropogon contortus* but by *Apluda varia* and *Setaria intermedia.*

Tegur. An area of 238 acres near the village of Tegur was taken up for cattle breeding in 1909. The vegetation was then examined and consisted mainly of *Andropogon contortus* and *Anthistiria ciliata.* The most notable non-grass plant visible was *Linum mysorense.*

In 1919 a quadrat was laid out in an area typical of most of the farm. This quadrat had *Andropogon contortus* dominant, *Anthistiria ciliata* subdominant. Other species present were *Sopubia delphinifolia, Tripogon Jacquemontii* and an *Alysicarpus* species.

From time to time the quadrat was examined but showed no great change. The last occasion was on October 21,1924, when *Andropogon contortus* was still dominant. Other species present were *Anthistiria ciliata, Andropogon pertusus, Arthraxon Meeboldii and Desmodium triflorum.* The area had been grazed and cut.

It was apparent, therefore, that no great change was coming over the vegetation and that *Andropogon contortus* remained master of the situation.

This is the case over the whole of the farm. *Andropogon contortus* remains dominant, but in addition there are large pure areas of *Anthistiria ciliata*. The presence of the latter species appears to be markedly determined by the presence of water. It occurs on the borders of tanks, in low-lying parts of the fields and along shallow eroded channels where the rain water tends to run. Such channels are traced in the vegetation above most markedly by the line of *Anthistiria* of a brownish green colour that stands out in the black and silver of the flowering *Andropogon contortus*.

We cannot say whether the *Andropogon* and *Anthistiria* have altered relatively in the proportion of the farm which they occupy, but we think there is no great change.

Here then apparently an *Andropogon contortus* association is very stable in the given conditions. These are the cutting for hay followed by moderate grazing. But we prefer to discuss this in the special chapter on this species.

In the Eastern Grassveld of South Africa and in the transitional belt between Karoo and Eastern Grassveld Bews[1] reports the dominance of a similar association. He says with regard to the transitional belt :—" The *Aristida-Eragrostis-Sporobolus* associes, however, if the succession is not kept back by grass burning, slowly passes into *Anthistiria-Andropogon* veld, which is the climax stage for the most part in Eastern Grassveld." In the Eastern Grassveld, he says " *Anthistiria-Andropogon* associations are the commonest, in fact the whole formation is practically made up of them. " It is plain therefore that both in South Africa and in India this stage is a stable one.

The behaviour of Anthistiria ciliata. There is the strongest evidence from the observations of several years that *Anthistiria ciliata* is the first invader of land that has been cultivated and then abandoned. In 1920, Mr. Salimath, B.Ag., then Inspector of Agriculture, Dharwar District, and later Deputy Director of Agriculture, Southern Division, recorded his observations that *Anthistiria ciliata* was the first colonizer of abandoned rice beds. In 1924, he informed us that in the so-called " koomri " cultivation of poor land, practised in Khanapur Taluka and Chandgad Mahal in the Belgaum District by the cultivators (a process whereby the jungle is destroyed and cultivation practised for a year only) *Anthistiria ciliata* is the first species in the field when the land is left to nature again. Generally speaking, he states that in grassland with a mixed population of *Anthistiria ciliata* and *Andropogon contortus* if one ploughs, harrows and prepares the ground as for a seedbed and then abandons it, *Anthistiria ciliata* dominates for the first four or five years. *Andropogon contortus* is by then creeping in, and unless water and silt come into the field and give conditions more favourable for the *Anthistiria*, the *Andropogon contortus* will finally dominate. We have seen in other places, for example markedly at Nasik, that *Anthistiria ciliata* was the dominant grass round the edge of cultivated fields, in parts which had been turned up by the plough and by the animals

[1] Bews, J. W. *Grasses and Grasslands of South Africa*, pp. 106, 11".

but which had not been sown or weeded. Away from the edge of the field *Anthistiria ciliata* was found but as only one component of a mixed vegetation which included *Chloris virgata, Andropogon caricosus, Andropogon schœnanthus, Andropogon contortus* and *Setaria intermedia.*

We have here apparently a stable type of grassland consisting mainly of *Andropogon contortus* with *Anthistiria ciliata* where edaphic conditions favour that species. In more moist soil *Andropogon Lawsoni* is dominant. Throughout the land there is a bottom growth of small plants unimportant for fodder. The climax formation as indicated by the jungle in immediate contact with the farm (a portion of this jungle has just been taken in for additional grazing) is forest consisting of *Tectona grandis, Butea frondosa, Phyllanthus emblica, Carissa carandas, Lantana camara,* and *Cassia auriculata.* The subclimax grassland cannot be said to have altered within the fifteen years just gone. The grass (*Andropogon contortus*) is cut for hay just before the spears harden, and makes fair feed in this condition. It is thereafter grazed. All attempts to establish other species have failed with two exceptions, namely, one plot of *Andropogon annulatus* and one plot of *Ischæmum laxum,* both of which seem to be favoured by rich deep soil and ample soil water. All other species have been quickly overcome by the invading *Anthistiria* followed by the final *Andropogon contortus.* Grazing, cutting and burning have produced little effect on the *Andropogon contortus.*

The whole of the neighbourhood was not this *Anthistiria-Andropogon* association. On a slope near by which was apparently going back to jungle, we found a low vegetation with *Andropogon pertusus* and *Andropogon Monticola* as the dominant grasses. The lower flat lands were dominated by *Anthistiria* and *Andropogon contortus.*

Belgaum. In the neighbourhood of Belgaum town itself are extensive grass lands. The rock underlying them is laterite and the contours of the land are long sweeping curves, giving the impression of downs. The soil is not deep in most cases, but in the depressions between the crests of the downs considerable soil may accumulate in pockets. In the late rains there is abundance of grass on these downs and where it has been reserved for cutting it may stand from three to five feet tall.

Our observations on the Belgaum grasslands began in October 1920 when one of us had occasion to spend some time at the Belgaum Vaccine Institute.

This institute produces vaccine lymph for the protection against small-pox and for this reason has to have handy a supply of calves. These are supplied by contractors, kept at the Institute for 6 weeks, during which time they graze on the Institute lands, and are then sent out and not used again. One set of calves after another are thus on the land. The average number of calves on the land at any one time is 150. The total area on which they graze is 72 acres.

The place was visited at various times and finally in October 1924. There was no marked alteration in the vegetation during this time.

The whole area is open to all the calves throughout the year. Consequently they graze all over the place and the whole vegetation is kept very hardly grazed down and in the early rains considerably trampled. In October 1924, therefore, the actual visible herbage was short, moderately open, and consisted largely of *Andropogon contortus* with some *Andropogon pertusus* mixed with it. The main ruderal is the endemic *Senecio belgaumensis* which is a sure indication of over-grazing and especially of trampling, being dominant in the neighbourhood of water-troughs where cattle come daily, and on the paths and stamping grounds of the cattle.

Other grasses present but in small quantity and scattered are *Ischæmum laxum, Anthistiria ciliata, Andropogon Monticola, Lophopogon tridentatus, Apluda varia, Andropogon annulatus, Andropogon caricosus, Arthraxon ciliaris,* and *Ischæmum ciliare.*

Ruderals other than *Senecio belgaumensis* were *Justicia simplex,* and *Mollugo pentaphylla.*

Reinvasion of denuded areas was markedly demonstrated on one or two golf "browns" that had been made but had been left to themselves since 1922. These had been first colonized by the composite *Sonchus* species. *Andropogon contortus stumps* were well established on the "browns," along with *Tripogon Roxburghianus* and *Justicia simplex.*

For the better study of succession the Director of the Institute kindly fenced two areas and permitted us to use these for observation and experiment. In the first of these, of one acre in extent, which was fenced in 1923 August, we ploughed up the middle third in May 1924 and resowed it with the suitable mixture of seeds in June 1924.

The other was merely enclosed and left to itself. It measured 1 acre and was fenced in August 1923.

Both areas bore originally *Andropogon contortus* dominant.

On studying these in October 1924 the following observations were made :—

Plot I. Untouched portions. *Andropogon contortus* dominant.

Plot I. Ploughed and reseeded strip. Sowing a failure. Ground poorly covered with vegetation and most of it ruderals, *viz., Justicia simplex, Mollugo pentaphylla* and along with plenty of *Senecio Belgaumensis.* There were stray plants of the sown *Anthistiria ciliata, Apluda varia,* and *Ischæmum laxum,* and germination had been worst at the western end. *Cassia pumilis* and the fern-leaved weed *Pimpinella adscendens* were also obvious.

There was no marked reinvasion of *Andropogon contortus.* This land has been left untouched to see what the next stage in the succession will be, and particularly whether *Andropogon contortus* will come back. The soil is very poor and shallow.

Plot II. Merely enclosed. Here also *Andropogon contortus* was dominant, but there was a greater proportion of other grasses, including *Ischæmum laxum, Andropogon pertusus, Arthraxon ciliaris, Anthistiria ciliata, Andropogon annulatus* and

Ischæmum ciliare. In addition there was a bottom growth of the small *Panicum trypheron* and of *Manisuris granularis.*

This is a very much more promising plot and it also has been left to see what will happen.

Of parasites we found *Striga euphrasioides* rare and a good deal of *Sopubia delphinifolia*, in two forms one with a white and the other with a brown corolla.

In a *nala* we found at the bottom near the gravel *Andropogon annulatus* and *caricosus*, *Anthistiria ciliata*, and on the upper slopes of the *nala* side *Andropogon pertusus* and *Cymbopogon Martini.*

Land at the village of Benkanhalli on the farm of Mr. Phatarphekar. About four miles from Belgaum is the farm of a family called Phatarphekar one of whom is a graduate of the Poona College of Agriculture. This family has for years devoted itself to agriculture, horticulture and the improvement of village conditions. On the land of their farm is a good deal of grassland and the part we saw had a good deal of *Anthistiria ciliata*, along with *Andropogon pertusus*, *Andropogon contortus*, and *Ischæmum ciliare.*

Here we found an unconsciously planned experiment which confirmed what we had learned regarding the behaviour of *Anthistiria ciliata* at Tegur. The following four plots were visible :—

I. Ploughed in June 1924 and planted with sweet potatoes.

II. Ploughed in June 1923, and planted then with sweet potatoes. No crop in 1924.

III. Ploughed in June 1922, untouched since.

In all three plots *Anthistiria ciliata* had invaded. In plot I, it was just commencing. In plot II, it had made an excellent stand, while plot III was practically a pure culture of the grass. It was very noticeable that while the *Anthistiria* on the untouched land was about eighteen inches in height, that on the ploughed land was over three feet in height and in some cases five feet. There was as yet no indication of effective invasion of *Andropogon contortus.*

Between Belgaum town and this farm at the top of one of the down like curves is a very fine area of uncut grass. This turned out to be *Anthistiria ciliata* along with the rare grass *Andropogon Ritchei*, which superficially resembles *Andropogon contortus* but strikes one at once as different on account of the very tawny hairs on the glumes.

There is here magnificent grassland which only needs proper treatment to develop excellent grass. Such portions as have been kept for cutting and have not been overgrazed naturally develop good stands of grass. Poor soil overgrazed develops *Andropogon contortus*, but along with it grow many other species which would get their chance if there were scientific management. We think it likely that on shallow poor soil *Andropogon contortus* would be replaced first by *A. pertusus* and then by *A. annulatus*, while on deeper looser soils *Anthistiria ciliata* would come in first and later other species including *A. annulatus.*

VI. Notes on individual species of grasses.

We have now indicated briefly the nature of the different kinds of grassland in the Bombay Presidency. Before dicussing the practical side of the problem it will be well to deal with certain of the more important species found on these grasslands.

1. *Andropogon contortus.*

(Plate IV, fig. 2.)

In the Bombay Presidency there are several grasses which may justly be called spear grasses. Of these the biggest is *Andropogon triticeus*, of which the awns are huge. This grass, however, stands so high and is so late that the spears do not give much trouble to man or beast. On the other hand the various species of *Aristida* are extraordinarily troublesome. They are early in ripening and their fruits with their awns form a close dry fluff near the earth which men and animals carry away with them much to their discomfort. *Andropogon contortus*, however, is the worst of them all as the spears are able to penetrate any clothing short of leather, and the stratum of spears is a little higher up in the grass vegetation than that of *Aristida* and gets one around the leg below the knee and down to the ankle. The exact nature of these spears we shall discuss later. At present we need only say that they are the fruits with their attached awns.

As soon as these awns begin to form, the grass is avoided by animals. This we have seen again and again in various places, and markedly so in the newly acquired jungle area at Tegur in 1924, where the cattle had grazed round and up to patches of this grass but had left them carefully alone.

Cattle will eat this grass when in fruit if there is no other feed, and occasionally eat it along with other species when these grow mixed together. The cattle may then suffer considerably from the spears. The gums and buccal mucosa are injured, and the mouth gets sore. The awns get stuck between the molars and we have seen great balls of these fruits and awns removed from the cheeks of cattle. The wounds in the mouth produced by these spears form easy openings for disease germs, so that there is indirect as well as direct damage from eating the grass in fruit. In addition, at this stage the grass has lost much of its feeding value. (Table 1 on page 43.)

Such ill effects on stock are common to several grasses with similar awns. For example, Williams, in his *Grasses and Forage Plants of the Dakotas* (1897) states with reference to *Hordeum jubatum* (Squirrel-tail) :—

> " This grass has become very abundant throughout nearly all parts of the North-west. It furnishes a considerable amount of good pasturage early in the season, but later becomes a bad pest. The rough " beards " work into the mouths of stock especially horses, and cause ulcerated

> sores. Not infrequently the animal becomes almost unable to eat, and unless promptly relieved may be permanently injured. The "beards" are also a source of annoyance to any one walking through a field containing the pest, as they work into the clothing and can only be dislodged with difficulty."

All the above might be applied word for word to *Andropogon contortus.*

Sampson[1] mentioned silmilar effects on animals from *Stipa occidentalis* (porcupine grass).

There is great depression of digestion in cattle fed on grass at this stage, which may be due partly to the fibrous nature of the feed and possibly partly due to irritation by awns that have got into the intestines.

In its earlier conditions, before the awns are formed, this grass is readily eaten. In fact it forms the bulk of the existing grazing on much of the Deccan and in the Southern Maratha country. In the poorer soils of Gujarat also it forms a great proportion of the early grazing. It can also be made into excellent hay if taken at the right time, *i.e.*, just when the flowers appear and while the awns are still soft. Major R. S. Scott, in charge of Remount Department of the Southern Command, informs us that at the Hapur Remount Depot, Babugarh, U. P., this grass grows to a height of about four feet and makes excellent hay. Babugarh is favoured in having dry weather at the time when the grass is in the necessary condition. At Tegur in the Southern Maratha country, Mr. S. S. Salimath, Deputy Director of Agriculture, annually makes excellent hay from *Andropogon contortus,* but there he is more at the mercy of the weather. However, with a field drying (not stacked) of twenty-four hours after cutting, he gets the grass sufficiently dry to put into its final stack. In October 1924, we saw some fine hay which had been stacked since the same month in 1923 and which smelt and looked good.

Various attempts have been made to deal with the spears. At Tegur an attempt was made to remove the spears when ripe and about to fall, by means of an implement like a huge comb. This consisted of a plank with iron nails projecting out of it, and was drawn through the ripe grass by bullocks. It was claimed that a man with this implement could remove the spears from four acres of land in a day. A mower and a heavy rake were worked behind the comb. The method has now been discarded in favour of making hay from the grass at an earlier stage when fibre is less and nutritive elements more.

We give in Table I (p. 43) analyses of *Andropogon contortus* taken at various times and in various stages of ripeness. For comparison we attach analyses of *Anopogon annulatus,* the best wild fodder grass we know, and also of Nilwa *jowar* (a fodder variety of *Andropogon Sorghum*). From this table it will be observed :—

(1) That in the green grass (*Andropogon contortus*) the percentages of albuminoids and carbohydrates are higher than in either *Andropogon annula-*

[1] Sampson, A. W. Important Range Plants. *U. S. A. Dept. of Agri. Bull. No.* 545, 1917, p. 10.

tus or Nilwa *jowar,* though the percentage of albuminoids in the Ganeshkhind grass drops at once after flowering.

(2) That the woody fibre starts to increase at flowering and goes up to a considerable figure.

(3) That the water percentage drops very low indeed in the dry grass.

We can see therefore that it is a good feeding grass but must be used before flowering or not later than flowering. As cattle will not usually touch it when it flowers even when the awns are soft, the only treatment then is either to make hay or silage.

It has been found possible to make excellent silage from *Andropogon contortus.* At Balegaum in the Nasik District a concrete silo 14½ feet in diameter and 16½ feet in depth was built by the department in 1918. In 1921 this was filled with 23,000 lb. green *Andropogon contortus.* In March the silage weighed 15,755 lb. and was sold to the local municipality at the rate of Rs. 4 per 1,000 lb. It was good stuff and readily eaten.

Another method of treatment, and one specially suitable for areas of plentiful and late rainfall, is to take several cuttings of this grass. At Bankapur we saw *Andropogon contortus* which had been cut on August 25, 1924, and which had made a fine low thick growth of most edible herbage by October 19, 1924. Of course, sooner or later the grass will flower, but it is obviously possible to get a good deal more out of it than has been imagined.

Our mention of repeated cutting and of cutting the grass while in flower raised the question whether such treatment if continued for some years will eventually kill the plants, by exhausting their vegetative growth and preventing reproduction by seed. Concerning this we have at present no facts, except that in Tegur where the hay-making process has been in vogue for some years there is no obvious diminution of the species.

Why should we attempt to exterminate or replace this grass if it suits poor land and small rainfall, gives grazing, cutting silage and hay ? Given a solid block of this pure species, it is fairly easy to manage it as it ought to be managed, but the conditions that we have to consider are such that it is mixed up with other species, some better, some poorer. It is not managed as it should be managed, and it rapidly matures its awns and becomes useless and even dangerous. It tends to increase and it is a nuisance on account of the spears. If we could get a non-awned *Andropogon contortus* then we should consider the problem of poor grazing lands practically solved, but as long as these awns remain so long will the problem remain. In addition, the matter is complicated by the fact that there appear to be at least two varieties of this grass with different characters, one small, early and annual, the other tall, late and perennial. All our foregoing remarks as to cutting and grazing and hay-making must be taken as referring to the perennial variety. The problem of replacing spear grass brings us at once to its ecology.

The following are the remarks of Griffiths, Bidwell and Goodrich[1] regarding *Andropogon contortus* :—

" *Heteropogon contortus,* a beard grass with long twisted darkbrown to black awns, is very characteristic of the native grass flora of many situations from central Texas to Arizona and southward into Mexico. It produces a quality of feed very similar to that of some of the larger species of *Andropogon.* On the whole, it is probably not grazed so extensively as those species. Some sheep growers in Southern Texas especially deplore its presence on account of the injury which the awns do in working into the fleece and flesh of their flocks. Anyone who has walked through a patch of this grass when mature will readily recognize the injury that it may do to sheep. However, cattle in Southern Arizona graze it to the ground very frequently. In some situations, in the sandy arid mountains, it grows thick over small areas, but usually it is distinctively a bunch grass, growing only in scattered bunches among other vegetation.

" (Sample) No. 8397 was collected at Green, Tex., August 14, 1906. The plants were in early maturity and were cut about 3 inches from the ground. Many of the lower culm leaves were dead. No. 9589 was collected in the foothills of the Santa Rita mountains, Ariz., September 16, 1908. The sample was duplicated on account of the viscoid sweet gummy secretion which appeared upon the inflorescence of the plants.

This is a very common phenomenon in this section.

Material	Percentage of moisture	Waterfree basis (per cent.)		
		Ash	Ether extract	(Crude fibre)
Our sample No. 8397 . . .	9·06	7·44	1·34	34·37
Our sample No. 9589 . . .	1·73	4·58	1·54	32·10
	Nitrogen free extract	Protein	Pentosans	
	51·93	4·82	27·46	
	57·65	4·13	24·00	,,

Ecology of Andropogon contortus. We have found this species everywhere. In central, northern and southern Bombay it is easily found, and in the coastal districts is also present but less visible, probably because the climate favours the growth of other grasses which crush it out. It is specially the grass of poor rocky land. In Tegur it was replaced in wetter parts by *Anthistiria ciliata.* At Pimpalgaon

[1] Griffiths, David; Bidwell, George L.; Goodrich, Charles E. Native Pasture Grasses of the United States. *U. S. Dept. of Agril. Bull.* 201, 1915, p. 26.

near Nasik in a pure stand of *Andropogon Monticola* and *Andropogon purpureo-sericeus*, we found *Andropogon contortus* wherever the water had eroded the surface soil away and left gravel and loose small pieces of rock. In very poor land the *Aristida* species tend to dominate, and on very hilly parts *Andropogon Monticola* and *A. triticeus* tend to increase. It is on the moderately poor land that is not much on the slope that we find it most, though it occupies the hills also and is found in the poorest land. When it does take hold it is a remarkably stable community, and apparently nothing short of digging it out will shift it. In this connection we may quote an experiment carried on over several years at Tegur.

This experiment was begun in 1920 and carried on continuously till October 1924 when the last observations recorded in this paper were made. Four plots of pure spear grass were chosen side by side. Each of these was 2 gunthas in area. Annually one was cut, one was grazed, one was burned and one was kept as a control. From year to year there appeared very little difference between these plots when examined at the time of flowering. The following are the observations on 21st October 1924.

Grazed plot. At this stage when the grass was in fruit the cattle would eat nothing and merely lay on the grass. It was a good stand of *Andropogon contortus* with little else in it, and more or less flattened with animals lying on it.

Cut plot. A good stand of *Andropogon contortus* in fruit. There was some *Andropogon Monticola* visible in it, also the grass *Ischæmum ciliare* and the parasite *Sopubia delphinifolia.*

Burned plot. A good stand of *Andropogon contortus* in fruit, with much more *Andropogon Monticola.*

Control plot. A good stand of *Andropogon contortus* in fruit along with *Aristida redacta* and *Ischæmum ciliare.*

There was no difference between these plots to the casual observer. On entering the plots, the only difference that could be called at all worth recording was the greater amount of *Andropogon Monticola* in the burned plot. From the point of view of eradication or even reduction all treatments were equally ineffective.

The repeated burning which the land round Kalas undergoes, and the burning done both deliberately and accidentally within the fenced plot at Kalas have shown us that burning does not reduce this grass. On the hills near Poona the same is the experience.

On the other hand, we cannot definitely say that burning tends to spread or encourage it.

Cutting and grazing seem to have little effect.

The only thing that seems really to affect it is the uprooting of it by the plough. We have already mentioned when dealing with conditions at Tegur and Belgaum that when land bearing a mixed population of *Anthistiria ciliata* and *Andropogon contortus* is ploughed and harrowed, then *Anthistiria ciliata* is the first to reinvade the cultivated plot and continues to be so for some four or five years. Thereafter

Andropogon contortus comes creeping in, and unless soil conditions are specially favourable to *Anthistiria* (*i. e.*, more soil water) then *Andropogon contortus* will finally dominate.

L. B. Kulkarni was successful in eradicating *Andropogon contortus* from the plots in the Government House, Ganeshkhind, Poona, on which he experimented. These were ploughed and cultivated in the hot weather and reseeded with other wild grasses in the two succeeding rainy seasons. These plots were fenced and cattle kept off them till 1922 up to which time there had been no reinvasion of *Andropogon contortus*. In 1922 the plots were opened to grazing but from August to October 1923 they were again closed. Thereafter they were open continuously. Although *Andropogon contortus* is dominant in the adjacent land it has not reinvaded the reseeded area. There is plenty of opportunity for it to do so as the vegetation therein is by no means close. We should mention here that *Anthistiria ciliata* is not common on this area, and hence has not had a chance to invade. In addition we think that *Anthistiria ciliata* needs a heavier rainfall.

At Kalas, on the other hand, the behaviour of *Andropogon contortus* has been somewhat different. The middle reseeded strip was treated similarly to the Government House plots, but did not receive the same close attention, owing to its greater distance from headquarters. As we showed in the chapter on Kalas, *Andropogon contortus* has been entirely ousted in the lower levels, where water accumulates, by other grasses, and in the higher levels is gradually being squeezed out by the tussock grasses *Andropogon Monticola*, and *Ischæmum laxum*. This process, however, is very slow and in the intervening spaces, *Andropogon contortus* flourishes as before. One could easily imagine a close stand of the perennial tussock grasses smothering the *Andropogon contortus*, but until that close stand is attained the spear grass will always have its chance. Hence the argument for helping nature by planting artificially small stumps of the perennial grasses to fill up the bare spaces.

Since the presence or otherwise of *Andropogon contortus* seems to be considerably controlled by soil moisture we made some analyses of soils in which this species was growing with the following results.

In areas where *Andropogon contortus* is prominent, soil moisture varies from 3 to 4 per cent. ; where *Andropogon contortus* gets scarce in lieu of *A. annulatus* and *A. caricosus*, it varies from 5 to 6 per cent. ; lastly where *A. contortus* is entirely absent and *A. annulatus* and *Iseilema* species dominate, it varies from 8 to 9 per cent.

The remarks of C. K. McClelland[1] regarding *Andropogon contortus* in Hawaii are worth quoting :—

" *Andropogon* (*Heteropogon*) *contortus*, twisted beard grass, tangle head, pili, is well known, being widely distributed. It occurs from sea-level to nearly 5,000

[1] McClelland, C K. Grasses and Forage plants of Hawaii. *Hawaii Agri. Expt, St, Bull.* 36, p. 27. 1915.

feet, although it thrives best below about 1,500 feet. It formerly covered larger areas than at present but has been destroyed or crowded out by overstocking and by encroaching of Hilo, manienie, pilipiliula and other grasses. The old Hawaiians utilized this grass in making their grass houses. There are extensive areas of it on western Holokai, on Lansi, in the valleys of Maui, and on leeward Hawaii. Over large areas in other regions the Pili has been nearly eradicated and it is only in the inaccessible places along the sides of steep gulches that occasional clumps may be seen. The grass makes a rapid growth, starting up after the first showers, but after seeding it becomes dry and brown. It may seed at irregular intervals, depending upon the distribution and amount of rainfall. The green growth is tender and palatable, but the brown stems are coarse and tough, and can be recommended only as maintenance feed for mature animals, although the disappearance of the grass as noted is due to grazing of the old plants as well as of the fresh growth. There is said to be a comparatively small shrinkage in cattle fattened on pili grass. Although the grass is perennial it is necessary to insure reseeding by removal of the stock since many clumps are uprooted or injured by the stock. Pili seems to be "coming back" upon certain lower areas of the Molokai ranch, where careful management is being exercised. On dry lands at lower elevations an effort should be made to retain pili by never overstocking, and by allowing rest at intervals. The seeds are quite difficult to collect and it would be tedious work to make new seedings over extensive areas. With imperfect stands of pili about 15 acres per head of cattle are required."

Early in 1924 it was decided to apply to the study of *Andropogon contortus* the same intensive methods that had yielded such excellent results in the case of the study of *Cyperus rotundus*, and accordingly a close investigation of the plant and of its life-history was undertaken. The following are some of the results so far obtained.

Morphology. This grass is mentioned by all botanists who have dealt with Indian grasses. The following is Hooker's description.

"Stems 1-5 ft. erect or decumbent below, densely tufted, simple or fastigiately branched, compressed towards the base. Leaves 6-18 in., narrow, glabrous or hairy, especially near the base rather glaucous rigid, margins and upper surfaces scabrid; sheaths compressed, keeled. Spikes with the lower 2-6 pairs of spikelets male with coherent joints; joints of upper (fem.) portion very short and curved callus bearded with brown hairs. Sessile (fem.) spikelets $\frac{1}{4}$ in., gl. I coriaceous, glabrous or hispid, many-nerved, tip membranous; II coriaceous, 3-nerved; III oblong hyaline, embracing the long slender ovary, tip ciliate, IV awn stout, column hirsute. Pedicelled spikelets $\frac{1}{3}$ to $\frac{1}{2}$ in. pedicel very short; gl. I lanceolate, obliquely twisted, herbaceous, keels margined or unequally winged; II membranous acute, 3-nerved, ciliate; pales minute, ciliate. Sessile spikelets of the homogamous pairs, like the pedicelled, more or less covered with tubercle-based hairs. Hackel has 2 varieties and 5 subvarieties (excluding Polystachyus) of this widely distributed plant founded

chiefly on the number and position of the tubercle-based bristles or the male spikelets. They appear to me to be too inconstant for definition."

The spear (Fig. 4). The so-called spear is the fruit with its attached glumes one

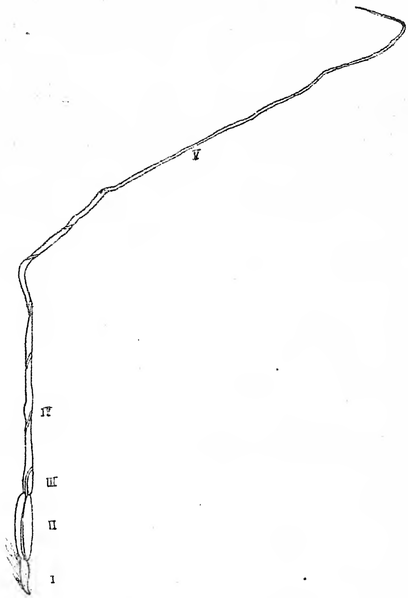


Fig. 4.

The fruit and its attachment.

I. Callus bearded with tawny hairs; II. Seed; III. Bulbous basal portion of the awn; IV. The spirally running channel; V. Wiry tail, ending in a fine point.

of which carries the awn. The spear is best understood from the figure. Let us describe it from the point upwards.

The actual point is the "callus" which is the prolongation downwards of the outer glumes at the point of its insertion on the rachilla. This is hard and pointed and is the penetrating end of the spear. It has a barb on it formed by a tuft of stiff hairs. These effectively prevent the extraction of the fruit after insertion into any

material. If the awn is pulled after such insertion then the awn comes away, leaving the fruit in the material.

The fruit is a caryopsis, of the average length of 7 millimetres and of the average breadth of one millimetre. What apparently is the seed coat is really a covering formed by the persistent glumes. The lower involucral glume has many nerves and its strongly incurved margins appear as too deep furrows on the ventral side of the fruit. The awn which seems to be inserted on the apex of the fruit is really the fourth glume, and is practically all awn, and expanded glume being absent. It is this fourth glume that comes away when pulled.

The awn shows two main parts, the column and the tail. The column is really linear and flat but has its margins rolled inwards so that it forms a tube. It is twisted so that the line of the margins appears as a spiral marking all round the column. The column is black and hairy. The tail is finer, not channeled, long, brown and wiry, and ends in a fine tip of lighter colour. The whole thing is reminiscent of a whiphandle, whip lash and its cutting point.

The awn seen under the low power of a compound microscope shows many minute alternate ridges and furrows, the furrows being whitish coloured.

Physiology of the spear. When the fruits are ripe they break off from the rachis and are found hanging on to the top of the vegetation in clumps, their awns twisted together. From this position they are dislodged by various agencies, and finally reach the ground. Here when the next year's rain comes they germinate.

The awn is astonishingly hygroscopic, and when wetted untwists with great rapidity, retwisting when the water evaporates from it. We made some experiments on the movements of these awns, of which the following may be cited.

One spear at a time was placed on the surface of wet blotting paper and the time taken for its movements to be completed was taken. These times were 1½, 2, 3, 4, 6 minutes. During these movements the whole spear writhed and twisted, raising either end, and turning completely over several times.

In addition, experiments were made by fixing the fruit in a cork and dipping the awn in water, then standing the cork up and noting the number of revolutions and the time taken to unwind itself completely. These were 3¼, 4 and 2½ minutes for 5, 5½ and 8 revolutions respectively.

This character of movement is apparently possessed by other grasses with similar awns. Sampson[1] remarks regarding *Stipa occidentalis* :—" The seeds of porcupine grass are usually high in viability and reproduction is greatly fostered by the self-burial device of the seed, the alternate twisting and untwisting of the awn coupled with the sharp pointed appendage at the base of the seed."

There can be no doubt that these hygroscopic writhings help to bury the fruit in the ground. We have repeatedly found fruits so buried, with the fruit below ground and the awn sticking up above.

[1]Sampson, A. W. Plant succession in relation to Range Management. *U.S. Dept. of Agri. Bull.* 791, 1919, p. 30 footnote.

Germination of the fruit. The fruit germinates rapidly, the radicle usually appearing within 36 hours. The radicle always appears near the callus and generally pushes itself out through the line formed by the margins of the outer glume. The plumule comes out at the other end of the fruit, apparently growing up under the glumes and coming into the light at the top of them. Fig. 5 shows a four-days-

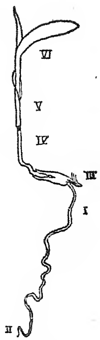


Fig. 5.

Andropogon contortus seedling (4 days old).

I. Tap root; II. Root cap; III. Seed; IV. Hypocotyl; V. Coleoptyle; VI. Mesocotyl

old seedling and its parts. The radicle is already well developed, and has begun to branch. The coleoptyle has burst and the first two true leaves have appeared.

Figs. 6 and 7 show later stages. It will be noted that the radicle persists as a very

Fig. 6.

Andropogon contortus seedling (25 days old).

I. Tap root; II, III. Adventitious roots; IV. Persistent glumes; V. Bud in the axil of the first leaf VI. First leaf; VII. Second leaf.

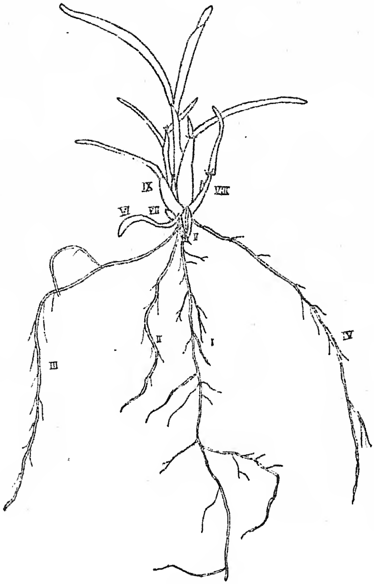


Fig. 7.

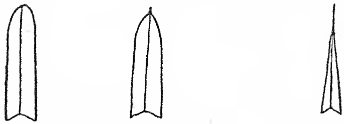
Andropogon contortus seedling (43 days old).

I. Tap root; II, III, IV. Adventitious roots; V. Persistent glumes; VI. First leaf; VII. Bud in the axil of the 1st leaf; VIII. IX. 2nd and 3rd leaves with buds in the axils that have sprouted.

useful tap root, that adventitious roots have developed to a considerable extent and that the plant has already begun to tiller. The plant then shows that rapidity in establishing itself which one learns to expect in plants that have been successful in adapting themselves to regions of precarious rainfall in poor soil.

The shape of apex of the leaves of the seedling alters as it grows. The coleoptyle as in most grasses is tubular, the first true leaf is acute. The leaves up to the fifth are acute or acuminate. Thereafter the apices gradually change to obtuse. This is a well marked stage, and at this period the grass can be easily recognised by

its blunt leaves. Later there is a change to abruptly acuminate and to acuminate, which is the condition of the leaves in the adult plant. Fig. 8 shows the different forms of apex.



I II III.

Fig. 8.

Three kinds of apices in Andropogon contortus leaves.

I. Obtuse; II. Abruptly acuminate; III. Acuminate.

Germination is (as wild grasses go) good. Both the small and the big variety of *Andropogon contortus* gave an average germination of fifty per cent. in tests made from May to November 1924 being an average of thirteen tests in the case of the big variety and of twelve tests in the case of the small variety.

Heating in a dry oven to 60° C. before putting to germinate increased and accelerated the germination to three times that of the control. Seeds germinated when buried up to one inch deep, but at two inches and below absolutely refused to germinate. The seeds germinated equally in all kinds of soils, but the seedlings were much stronger in good soils. This indicates that *Andropogon contortus* though a denizen of poor land responds to improved conditions.

Time from germination to flowering. Table II (p. 44) shows the time of sowing and flowering and the length of life of plants grown in pots. It will be noticed that the average length of life of the big variety is 116 days while that of the small variety is 76 days. We cannot lay much stress on these figures, however, as the tests are not simultaneous, and we know that length of life in grasses is influenced by the time of year when the seeds are sown. Moreover, there are more tests in one case than in the other. The figures, however, do show that flowering is on the whole rapid, but not anything like so rapid as the first colonists of poor ground, *Tripogon Roxburghianus*, for example.

Varieties of Andropogon contortus. In our observations at Kalas and elsewhere we noticed variability within the species, and early came to the conclusion that there must be definite varieties of *Andropogon contortus*. We can say with confidence that there are at least two varieties, differing markedly in size, habit, longevity, and in morphological characters. One is small and annual, the other large and perennial. This may account for conflicting statements by other writers as to the length of life of a plant of this species.

The following are brief descriptions of the two varieties :—The annual variety occurs in poor *mal* land and on rock it is decumbent, finally erect. Its height is from six to nine inches. The stems are not greatly compressed. The leaves are from one to four inches long. It flowers early after the first rains. There are one to seventeen pairs of spikelets. The awns are hairy and whitish and the outer glumes are hairy. The roots are shallow, spreading and thread-like. The perennial variety occurs in much richer soils (see succeeding paragraph). Its habit is spreading and later erect. Its height is from one and a half to three feet. The stems are much compressed. The leaves are from two to twelve inches. It flowers in October. There are from twenty-one to twenty-five pairs of spikelets, the awns are brownish and the outer glumes not so hairy. The roots are deep and wiry.

The following are analyses of soils from typical places where these two species were growing. The analyses were made in November 1920 after a monsoon rainfall of 21·54 inches, which had, however, ceased about six weeks earlier.

	Soil from beneath annual variety	Soil from beneath perennial variety
Moisture	1·83	3·46
Loss on ignition	3·48	8·26
Sand	48·89	58·94
Lime	0·13	0·17
Phosphoric acid	0·10	0·17
Potash	0·35	0·42
Nitrogen	0·06	0·12

In July 1923 after 26 cents of rain the water content (total water) of two similar sites was 3·66 per cent. from beneath the annual variety, and 7·19 per cent. from beneath the perennial variety.

It is plain, therefore, that the annual variety is a colonizer of much poorer soil than that on which the perennial flourishes. The Tegur *Andropogon contortus* is all of the perennial type. The annual type is usually found on the very shallow parts of Deccan soils.

These two types come true from seed, as we have experimentally tested in our nurseries and in field plots.

Bews[1] mentions *Andropogon contortus* as " an early flowering species which forms vernal aspect societies." This certainly does not correspond with our perennial variety but is true of the annual variety.

[1] Bews, J W. *Grasses and Grasslands of South Africa*, p. 117.

Summary. In *Andropogon contortus* we have a species well adapted to poor soil and dry conditions. It does not, however, represent the worst stages of a succession. Next below it comes a phase in which the *Aristidas* dominate.

Andropogon contortus gives a good fodder until the spears form. If made into hay or silage before these spears harden, the grass is most useful. The spears rapidly harden, however, and along with this there is an immediate drop in the feeding value of the grass as indicated by analyses.

Replacement of *Andropogon contortus* by other grasses has been successfully carried out at Government House, Poona. *Andropogon contortus* has never managed to get a footing among the *Andropogon pertusus* of the Agricultural College ridges at Poona. At Pimpalgaon Basvant it was found among *Andropogon Monticola* and *Andropogon purpureo-sericeus* only where erosion had left a soilless rocky channel.

Burning, cutting and grazing do not kill out the perennial variety at Tegur. At Tegur and elsewhere if the *Andropogon contortus* is destroyed by the plough it comes back very slowly but for the first few years *Anthistiria ciliata* dominates the ploughed portion.

We frankly admit that we are not anywhere near finality in our study of this species, but the indications are towards the following tentative conclusions :—

(1) If extirpation is wanted then there must be either one or more of the following changes in the environment :—
   (*a*) Ploughing up of the existing grass.
   (*b*) Alteration of the nature of the soil and especially of its water content.
   (*c*) Introduction of competing species.

(2) If utilization is desired then it must be by silage and hay-making not later than the first appearance of the spears.

(3) If the prevention of invasion by spear grass is desired then all that is necessary is the prevention of the killing of the existing cover by overgrazing or mechanical injury of other kinds.

TABLE I.

Different analyses of Andropogon contortus and its comparison with Andropogon annulatus and kadbi.

—	KALAS							GANESHKHIND		CENTRAL PROVINCES			
	GREEN AND IN FULL FLOWER											NILWA (FODDER)	
	A. contortus, big variety with awns and no roots, 5-1-21. Agric. Chemist	*A. contortus*, big variety without awns and no roots, 5-1-21. Agric. Chemist	*A. contortus*, small variety with awns and no roots, 5-1-21. Agric. Chemist	*A. contortus*, small variety without awns and no roots, 5-1-21. Agric. Chemist	*A. contortus*, 17-3-23. Agric. Chemist	*A. contortus*, dry grass. Agric. Chemist	*A. contortus* grass before flowering. Agric. Chemist	*A. contortus* grass in flower. Agric. Chemist	*A. contortus* grass after flower. Agric. Chemist	*A. contortus* dry grass	*A. annulatus* from Poona green	Green	Dry
Moisture	7·25	4·05	4·80	5·00	5·35	6·00	66·2	62·0	60·3	6·9	69·9	60·0	10·0
Ether extract	1·30	0·80	1·55	1·35	2·10	1·1	1·7	1·6	1·8	1·2	1·6	0·6	1·5
Albuminoids	3·63	2·56	2·25	1·81	3·50	2·2	2·4	2·4	1·7	2·1	2·1	1·5	5·7
Digestive carbohydrates.	44·42	47·99	47·30	46·34	50·80	44·5	22·7	22·2	20·4	50·2	13·5	20·3	41·6
Woody fibre	35·50	36·90	36·60	36·90	29·85	39·1	4·0	5·7	9·1	32·2	9·2	14·6	32·8
Ash	7·85	7·70	7·50	8·10	8·40	7·1	3·0	6·1	6·7	7·4	3·7	3·0	8·4

TABLE II.

Showing the time of sowing, flowering and the length of life of plants grown in pots.

Date of sowing	Big Variety		Small variety	
	Date of flowering	Date of dropping seed	Date of flowering	Date of dropping seed
17th May 1924	5-10-1924	8-11-1924	..	..
31st May 1924	..	..	30-9-1924	8-11-1924
21st June 1924	10-10-1924	15-11-1924	24-9-1924	9-11-1924
5th July 1924	14-10-1924	20-11-1924	2-10-1924	10-11-1924
19th July 1924	..	..	5-10-1924	10-11-1924
2nd August 1924	..	..	10-10-1924	2-11-1924
16th August 1924	25-10-1924	3-12-1924	..	..
30th August 1924	..	..	20-10-1924	28-11-1924
13th September 1924	..	..	5-11-1924	3-12-1924

2. *The Aristida species.*

Of these, there are three common on our poorest land, *viz.*, *A. redacta*, *A. funiculata* and *A. Adscenscionis*. They have the common character of the genus, namely, the tripartite awn, and the following differences in the awn between themselves.

A. redacta. This is the most easily recognised as two of the branches of the awn are very short, and the third long.

A. funiculata. The column (the undivided part) of the awn is up to two inches long and is twisted and scaberulous. One of the awn branches is slightly longer than the other two. The awn is articulate on the glume.

A. Adscenscionis. The column is not more than an inch long and the awn is not articulate on the glume.

These are grasses of low stature giving little foliage and poor feeding. They produce spears earlier than *Andropogon contortus*. Their spears are finer but very annoying. When dry in the awned condition an area of Aristida is mere tinder and a spark will start a fire that travels with great rapidity.

The conditions suitable for the *Aristidas* are, as we have seen at Kalas and elsewhere, open dry situations with poor shallow soil. It covers enormous areas in the very dry poor parts of the Deccan. Buffaloes have been seen to graze *Aristida funiculata* greedily when it is in the young state.

The *Aristidas* mark a stage between the lithophytes and *Andropogon contortus*. The Kalas quadrats indicate this, also observations in other similar areas. An

Aristida area will never advance unless grazing is restricted and soil water conserved. Very simple rude terracing even by six-inch walls of stones will help the latter improvement.

Other species of *Aristida*, referred to significantly as needle grass and poverty grass, are found in similar situations in America. In South Africa still other species occupy dry barren areas.

3. *Andropogon annulatus*, Forsk. and *Andropogon caricosus* L.

These two grasses are usually lumped together by hersdmen and given one vernacular name. In Marathi this name is Marvel, and in Gujrati Zinzvo.

There is a general consensus of opinion among all writers that these are specially good fodder grasses. This also is the opinion of farmers and herdsmen. It is also the opinion of the cattle who will sort these species out of a mixture and eat them first.

Regarding *Andropogon annulatus*, Lisboa[1] says, "It is considered an excellent fodder grass either in the green or dry state." Duthie[2] remarks, "It yields a considerable amount of fairly good fodder which is largely made use of." Rangachari[3] states, "This is another common grass flourishing in cultivated fields and gardens and seems to like sheltered places. This yields a considerable amount of fodder and stands cutting very well."

As to *Andropogon caricosus*, Lisboa[4] says that it is "esteemed as good fodder, eaten by cattle." Rangachari[5] says "This is a common grass flourishing on the bunds of paddy fields and in sheltered places where there is sufficient moisture in the soil. Cattle eat the grass eagerly both when young and in flower." McKerral[6] states that it is "common in the dry zone (of Burma) where it is perhaps the most important pasture grass."

The following are analyses of the grass (*A. annulatus*) :—

	Before flowering	In flower	After flowering
	Per cent.	Per cent.	Per cent
Moisture	69·90	65·93	65·40
Ether extract	1·60	1·70	1·72
Albuminoids	2·14	2·24	2·00
Carbohydrates	13·46	14·80	12·81
Woody fibre	9·20	11·59	14 26
Ash	3·70	3·74	3·81

[1] Lisboa. *Bombay Grasses*, p. 82.
[2] Duthie. *Fodder grasses of N. India*, p. 33.
[3] Rangachari. *The Common Fodder Grasses of the Madras Presidency.*
[4] Lisboa. *Bombay Grasses*, p. 81.
[5] Rangachari. *The Common Fodder Grasses of the Madras Presidency.*
[6] McKerral. The Commoner Grasses of Burma. *Dept. of Agri., Burma, Bull.* 20, p. 12, 1923.

Andropogon annulatus and *A. caricosus* are rather like one another as may be judged by the fact that they are lumped as one variety in the vernacular. They are botanically distinguished by the following marks :—

	Andropogon annulatus	*Andropogon caricosus*
Habit.	Medium size with terminal inflorescences.	Big and tufted with terminal and axillary inflorescences.
Nodal hairs on stem.	Long.	Short.
Inflorescence colour.	Purple.	Light purplish-green.
Inflorescence hairs.	Long.	Short.

Both are variable. Hackel[1] describes three varieties of *A. annulatus* (*genuinus decalvatus* and *Bladhii*) and Hooker[2] adds a fourth (*papillosus*). These differ from one another in hairiness. The present writers are not prepared to say that their observations entirely confirm this classification. Having regard to similar variability found in several other grass species, and in cultivated cereals, we are inclined to think that any attempt at botanical determination of varieties without genetic tests is premature. Of one fact we are convinced that both species, and especially *A. annulatus*, are variable. We have already shown that in the species *Andropogon contortus* there are two genetically distinct varieties, and we have confirmed this in cultures. The same method must be applied to other wild grasses if certainty is to be reached.

It seems to us that throughout the whole science of taxonomy it is now time that the practice of naming varieties and species from casually collected specimens, dried and pressed, should be stopped, and that the only scientific method of pure culture should be substituted.

Ecology of Marvel (*A. annulatus and A. caricosus considered as one*). We have already shown how Marvel dominates in the part of the Kalas plot where there is plenty of soil water. In recent years there has been rather too much water as is indicated by the increasingly swampy nature of the vegetation in No. II and No. VI quadrats. The effect on the Marvel is to develop a purple colour in the leaves and to stunt growth in the early rains.

We have also shown how this grass dominated in the compound of the Economic Botanist, Poona, in a lawn planted with *Cynodon dactylon,* and in an area where the normally dominant grass was *Andropogon pertusus,* in unwatered soil.

In the European cemetery at Poona in deep black soil Marvel is absolutely dominant to the exclusion of all other grasses. This soil is never grazed, but the grass is cut annually. In the poorer grazed soil outside the cemetery *Andropogon contortus* is the dominant grass.

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[1] Hackel. *Monograph Andropogon,* p. 479.
[2] Hooker. *Flora of British India,* Vol. VIII, p. 197.

We have shown that it is found at Chharodi in the part set aside for cutting. At Tegur it could not stand against the competition of *Anthistiria ciliata* and *Andropogon contortus*.

The natural conclusion is that in Deccan soils if the soil water is sufficient and if grazing is not severe Marvel does establish itself. The places where it has established itself at Kalas have a total soil water content in the dry season of 6·54 to 13·25 per cent. In Gujarat with its more retentive soil Marvel will usually establish itself along with other good grasses if it is not too heavily grazed. In the Southern Maratha Country it cannot establish itself in the typically *Andropogon contortus* tracts, but where there is heavier rainfall and more soil moisture we think establishment is possible. In the heavy rainfall areas of the coast it is not so prominent, but either on the coast with a lighter rainfall or a little way inland one gets Marvel (*e.g.*, as in the reclaimed land in Hansot or the jungle at Neral).

Bews[1] says "Another small group (of *Andropogon*) is confined to the semi-open veld, or dry rocky hillsides of the centre and west (of South Africa), *viz.*, *Andropogon Monticola* var. *trinii*, from Bechuanaland, which is noted by Stapf as also occurring in India, *A. ischaemum* var. *radicans*, *A. schimzii* and *A. annulatus*." He therefore allots it to conditions very similar to those in which we find it in India.

4. *Andropogon pertusus*, Willd.

Of this grass there seem to be many forms. Hackel[2] mentioned four Indian varieties, united by intermediates. Our remarks as to the taxonomic methods in the section on *Andropogon annulatus* and *A. caricosus* apply here also. We have seen on the hills of the Deccan a form with red wiry runners. In better soil the runners are not conspicuous. The distinguishing mark of the species is the pit in glume I of the sessile spikelets.

Hooker[3] states that the grass is both annual and perennial. Rangachari[4] calls it a perennial. Our observations indicate that a plant will last for at least twelve years.

We have mentioned this grass as common in the estate of the Poona College of Agriculture, in six inch deep soil, with a twenty-seven inch rainfall and moderate grazing. It is also common in the compounds of the College of Agriculture at Coimbatore. At Tegur in land near jungle with very shallow soil having a slope of 1 in 10 we found *A. pertusus* the dominant grass. There were also present there *A. Monticola* and *A. contortus*.

There is little doubt that it is drought-resistant. An Australian writer[5] says "some years ago I had this species growing on a lawn for which I found it a very

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[1] Bews, J. W. *Grasses and Grasslands of South Africa*, p. 55.
[2] Hackel. *Monograph Andropogon*, p. 479.
[3] Hooker. *Flora of British India*, Vol. VIII, p. 174.
[4] Rangachari. *A Handbook of Some South Indian Grasses*, p. 191.
[5] *Agri. Gaz. of N. S. W.*, IV, 82.

suitable grass, both for summer and winter. After being cut a few times it assumes a dwarf compact habit and is easily kept in order with other lawn grasses. I can recommend it as a lawn grass for some of the drier districts of the colony."

As to its fodder value Watt[1] says "It is an excellent grass for grazing and stacking." Duthie[2] says it is found in light soils and puts it among the first class fodder grasses. Rangachari[3] remarks "This is an excellent fodder grass and it grows quickly and stands cutting very well. Cattle eat this grass very well."

One occasionally comes across the statement that this grass has a smell which makes it unpalatable, as when McKerral[4] says, "Common in the dry zone and of some use, although some cultivators state that cattle dislike its bad smell and bitter taste."

We have seen it browsed with relish year after year. If there is anything in the statement as to bitter taste and smell it may refer to some variety, or it may be largely imagination. Where this grass is present it is to be encouraged. If well treated it will last, and if the soil moisture increases will tend to give way to even better grasses.

Bews[5] states that in South Africa *Andropogon pertusus* "occurs usually in the early stages of subseres but may be found in more stable veld." By this he means that the species *Andropogon pertusus* is usually found in the earlier stages of a succession back from land disturbed by cultivation or other interference but may persist in the later stages.

VII. The propagation of wild grasses by artificial seeding.

For some years the United States Department of Agriculture has conducted experiments in artificially reseeding worn out native pastures in the west, but practical results are limited to a small acreage of lands where soil and moisture conditions are very favourable. Even on such lands it is frequently a question whether the increase in fodder will justify the expense of seeding. Results also indicate that turf formers are the only grasses which will be maintained and will continue to spread from initial planting at high elevations, and that success has been had with native rather than exotic species.

In our conditions we have in our experiment successfully renovated a spear grass area at Poona by extirpating the existing vegetation and re-sowing with seeds of useful wild grasses. This experiment is described in detail in another publication by one of us. (L.B.K.).

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[1] Watt. *Dictionary of Economic Products of India*, Vol. III, p. 421.
[2] Duthie. *Fodder Grasses of N. India*, p. 72.
[3] Rangachari. *A Handbook of Some South Indian Grasses*, p. 192.
[4] McKerral, A. The Commoner Grasses of Burma. *Dept. of Agri., Burma, Bull.* 20, p. 12. 1923.
[5] Bews, J. W. *Grasses and Grasslands of South Africa*, p. 56, 1918.

At Kalas in the area whose ecology we have described earlier in this paper, we also tried reseeding. A strip down the middle of the area running its whole length was ploughed in 1920 (just after enclosure) and reseeded in June 1920 with a mixture of the following wild grasses :--

Grass	Amount in lb.
Andropogon purpureo-sericeus	70
A. Monticola	20
A. caricosus	10
A. pertusus	10
Thelepogon elegans.	25
Anthistiria ciliata	20
Ischæmum laxum	20
Apluda varia.	20

In addition the following wild leguminous plants were added in the hope that by their growth and decay they might add nitrogen to the soil—

Tephrosia purpurea	2
Psoralea corylifolia	1
Indigofera glandulosa	5

The plot on which these were sown amounted to about 2 acres. An early effect of this treating of the land was the appearance of a weed flora from among which *Vinca pusilla* was dominant. In the first two years *Andropogon purpureo-sericeus* showed a fair stand, especially in the low-lying area, but later practically disappeared. Of the other plants sown *Apluda varia* is fairly common and even dominant in some places, while *Tephrosia purpurea* is found here and there. Neither of these is found outside the reseeded strip. Otherwise the reseeded strip is similar to the rest of the area, the other grasses having failed to establish themselves and the check to the normal vegetation (due to ploughing) having been got over easily on account of continued enclosure.

The reason for lack of success in reseeding with wild grass seed is the generally unsatisfactory germination capacity of such seeds both in America and India. Certain wild species may have fairly high germination percentage but most of them give very low figures. The table below shows the results of tests carried out at the College of Agriculture, Poona, in 1915, 1920, 1921, and 1922.

One hundred seeds of each of the following species were put in small flower pots filled with fine sand. These pots were placed in big trays filled with water so as to keep the sand constantly moist. The pots were covered with glasses. Germinated seeds were removed daily and complete record of the number germinating each day was kept. The seeds were tested twice a year, namely, once in January or February that is after the seeds were collected and before they were finally stored in tins, and a second time in June or July that is before the seeds were used for sowing in the field.

Table showing results of germination tests.

Serial No.	Species tested	1915		1920		1921		1922	
		Time of collection, Nov.-Dec. 1914	Time of test, Jan.-June 1915	Time of collection, Nov.-Dec. 1919	Time of test, Feb.-June 920	Time of collection, Nov.-Dec. 1920	Time of test, Feb.-June 1921	Time of collection, Nov.-Dec. 1921	Time of test, Jan.-July 1922
		Percentage of germination							
1	*Andropogon caricosus*	..	..	35	69	11 5*	30	11	10
2	,, *Monticola*	1	11	0	1	–	–	–	–
3	,, *purpureo-sericeus*	3	51	0	29	2 10*	40	2	41
4	,, *pumilis*	1·5	9	0	22	–	–	0	1
5	,, *pertusus*	40	10	3	4	21 6*	28	21	16
6	,, *annulatus*	13	12	–	–	8 18*	36	8	17
7	*Iseilema Wightii*	0	16	–	–	7 2*	5	7	7
8	,, *anthephoroides*	1	–	–	–	2 3*	31	2	13
9	*Ischæmum sulcatum*	33·5	24	1	48	12 2*	16	12	20
10	,, *laxum*	–	–	–	–	1	9	1	33
11	*Apluda varia*	9	12	0	25	17 0*	16	17	19
12	*Anthistiria ciliata*	2·5	13	0	37	39 2*	28	39	33
13	*Thelepogon elegans*	15·5	–	0	6	0 4*	4	0	2
14	*Chloris barbata*	29·5	54	–	–	.	–	..	..
	Average percentage	12·4	21·4	4·3	26·7	10·9	22·0	10·0	18·4

– means seeds not tested.
* means pots kept outside the room.
0 means that seeds did not germinate.

Later tests gave similar figures. The highest value got in single tests were 80 per cent. for *Andropogon purpureo sericeus* and 70 per cent. in the case of *Andropogon contortus.*

The causes of the comparatively low germination percentage of most wild grasses are probably many. Among these may be—

(1) Varying maturity at time of collection, since grass plants mature their seeds from one or other end of the inflorescence.

(2) The possible need of a rest for the " after ripening " of the seeds of some species. In addition, one should remark that much so-called seed found in collected seed of wild grasses is not seed at all, but merely

empty husks. Such empty husks are produced either by spikelets that do not usually contain female flowers, or the spikelets in which the female flowers have failed to set fruit.

When we consider, then—

(1) that much collected seed of wild grasses consists of husks,
(2) that of the true seed the germination percentage is low,
(3) that of this low percentage many will not survive in field conditions, and
(4) that the collection of the seed is an expensive process,

we are forced to the conclusion that artificial reseeding of natural pastures will be rarely applicable as a means of renovating depleted grass lands.

VIII. The Burning of Grasslands.

During the dry season and especially in the hot weather grasslands in India are liable to take fire. In the carefully guarded area at Kalas we have had two fires due to (1) accident and (2) incendiarism. The area just outside the fence is burnt annually (accidentally) and only an efficient fireline prevented the protected area from *similar annual burning.* It should be mentioned that the inflammable vegetation outside the Kalas fence is very low in height (having been so heavily grazed) and small in bulk. In areas where tall grass is allowed to remain and dry up, the risks of fire are correspondingly greater.

The actual effects of such burning on grass lands in the Deccan have been observed at Kalas on (1) burnt quadrats, (2) the accidentally burnt area, (3) deliberately burnt strips.

The burning of quadrats did not decrease either the total number of plants present or the number of species represented. On the other hand, denuding by scraping put back the vegetation as to density and gave opportunity for weeds to colonise the bare areas. The accidentally burnt parts were unrecognisable from the unburnt parts at the end of the following rains. We have already mentioned on page 7 the effects of burning in forcing early growth, and the evil effects of undecayed vegetable matter lying on the soil as an impenetrable mulch.

Hole[1] has given some important data and conclusions regarding the effects of firing in the Dehra Dun Valley and its surrounding hills. Reference must be made to his original memoir for his full arguments, but he summarizes his facts by saying

" In addition to the direct action of fire on the grass plants, also, we have to consider another important point, *viz.*, the effect of fire upon the soil. It is obvious that any factor which decreases the water content of the soil, *ipso facto,* renders a locality unfavourable for the vigorous growth of robust mesophilous and hygrophilous species and tends to produce conditions suitable for the growth of more xerophilous plants.

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[1] Hole, R. S. On Some Forest Grasses and their Ecology. *Ind. For. Mem.*, I, 1, pp. 119-120, 1911.

"This is exactly what fire really does and it appears to act in two principal ways :—

(1) By directly destroying the humus which may exist in the surface soil and by effectually preventing any further addition to the existing supply through destruction of all dead leaves and organic debris.

(2) By altering the character of the clayey constituents of the soil in such a way that loam to a great extent loses its power of retaining water. The texture of the soil becomes coarser and percolation is increased."

Hole is dealing with a district that has an 80-inch rainfall and where coarse grasses, particularly *Saccharum Narenga* and *Saccharum Munja*, grow luxuriantly. In our heavy rainfall areas it is probable that we may have something like his conditions, but in none of the stations on which we have carried out experiments have we found that enormous coarse growth which is commonplace in the area of which he is treating. On the other hand, in the whole of the Deccan, most of Gujarat and the whole of the Southern Maratha Country it would be a cardinal error to do anything *to reduce* the water-holding power of the soil. In all these parts and especially in the Deccan we need to increase the waterholding power. We have already indicated that the establishment of *Andropogon annulatus* and *A. caricosus* in the Deccan seems to follow increase in water-content.

Bews[1] in South Africa comes to the conclusion that if the grassveld is of a primitive or semi-open type with species of *Aristida* or *Eragrostis* dominant (like much of the Deccan) burning prevents the plant succession from going any further. If the grassveld has developed further and carries *Anthistiria* as a dominant species (like some of our Southern Maratha Country grasslands) then burning sends the succession back a step to the *Aristida-Eragrostis* stage. If the grassveld carries tall coarse grasses (as in Hole's Dehra Dun area) the veld should be burned deliberately to send it back to the preceding *Anthistiria* stage.

These findings agree in the main with those of Hole, that burning tends to produce a more xerophilous type of vegetation.

It is plain then that, as a tentative procedure for Western India,

(1) we should, in the Deccan, Gujarat (except the coast) and the Southern Màratha Country, avoid burning. We should, however, take care to see that no dead vegetation accumulates but that the grass is cut or grazed close before the advent of the dry weather. We wish to increase the water-holding power of the soil. The dead material of grasses in bulk is produced at the end of the rains and is too sclerenchymatous to rot easily. During the rains, due to grazing and cutting and casual withering there is a small annual addition of humus that will gradually have its effect, if we can keep that effect from being annulled by fire in the dry weather.

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[1] Bews, J. W. *The Grasses and Grasslands of South Africa*, pp. 141-142, 1918.

The gradual increase of the stumps of perennial grasses also acts as a potent means for preventing run-off and with these two agents at work (increase of humus and of perennial stumps) the water-holding power of the land will gradually improve and the vegetation change from poor into good grassland.

(2) In areas of heavy rainfall, it may be necessary to burn if tall coarse grasses are likely to dominate, but the fact of a grassland merely being in a heavy rainfall area does not mean that it should therefore be burned. We have seen that at Mulund in a heavy rainfall area the grass cover was very meagre due to trampling and over-grazing. Again, in heavy areas the aim should be to have the grass cover off the land before the dry weather, leaving only short stubble, and burning only if necessary.

American experience of burning is as yet inconclusive. One of us (L.B.K.) saw some experiments in 1924. The following may be mentioned.

In the foothills of the Jornada Range Reserve, New Mexico, burning in February was done. In July the burnt area gave decidedly less hay than the unburnt one; there appeared abundant annual species including grasses in the burnt area; the grama grass (*Bouteloua olygostachya*) was killed out by burning.

In California in the Sierra mountains, burning of the foothills in August 1923 produced a dense growth of annual weeds with low forage value.

Experiments at Redding in California were not conclusive.

Experiments in Kansas rather favoured burning, but there the conditions are markedly different from the south and the results cannot be considered so applicable to Indian conditions.

IX. Conclusion.

"The first step towards the discovery of the most scientific and therefore the most economical and productive treatment" (of grassland) "is the careful and thorough study by trained investigators, of the natural composition, behaviour and succession of the vegetation.[1]"

In the preceding pages we have endeavoured to record what we have discovered as to the composition, behaviour and succession of the vegetation of certain grasslands in Western India. The results are hopeful. Very poor land in areas of moderate rainfall has produced under careful treatment useful stand of grass within five years. Salt land on the coast as it becomes drained carries good grass. Other coastal districts have excellent vegetation easily destroyed or caused to degenerate by trampling or over-grazing but quickly ameliorated by controlling these factors. In Gujarat and in the Southern Maratha Country very fine pasture can be developed with moderate care.

The Indian public and its legislators have been for some time alive to the need of such care and improvement. In 1915, the Honourable Maharaja Ranjit Sinha

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[1] *Nature*, August 23, 1924, Imperial Botanical Conference, p. 294.

put a question regarding the deterioration of Indian cattle and the provision of common grazing grounds in the Imperial Legislative Council. In 1919, Dr. Harold H. Mann, Director of Agriculture of the Bombay Presidency, brought to the notice of the Board of Agriculture the need for a systematic investigation of the improvement of grass areas as a measure against famine. In 1920, Sir Purshottamdas Thakurdas, in his capacity of trustee of the Cow Protection Society, memorialized the then Viceroy on matters affecting the welfare of cattle and insisted on India's capacity to produce all the fodder necessary for the upkeep of her cattle if proper arrangements were made.

What is now required is experiment on a large scale on the effects of certain treatments, particularly the American methods of deferred and rotational grazing modified as required for different tracts in India. We are fortunate in having in this matter the co-operation of some of the rich cattle protection societies in Western India and hope thereby to still further increase our knowledge on this important subject.

With the increasing demand on land for the growing of money crops, the increasing need for draught cattle and pure milk, and with the indications of recent researches in animal nutrition showing the value of grazing as against mere stall-feeding, it is plain that this important investigation must be carried much further as an integral part of the measures taken for the permanent enrichment of India.

APPENDIX.

Species found in the enclosed grass area at Kalas.

Natural order	Species
Papaveraceæ	*Argemone mexicana* L.
Capparidaceæ	*Cleome simplicifolia* HK f. & T.
	,, *viscosa* Linn.
Polygalaceæ	*Polygala erioptera* DC
	,, *chinensis* L.
Portulacaceæ	*Portulaca oleracea* L.
Malvaceæ	*Sida grewiodes* GP & R.
	Gossypium hirsutum L.
	Hibiscus micranthus. L. f.
Tiliaceæ	*Corchorus trilocularis* Burm.
Caryophyllaceæ	*Polycarpæa corymbosa* Lam.
Geraniaceæ	*Monsonia senegalensis* G & P.
Meliaceæ	*Azadirachta indica* Juss.
Rhamnaceæ	*Zizyphus jujuba* Lam.
Leguminosæ	*Heylandia latebrosa* DC.
	Rhynchosia minima DC.
	Alysicarpus monilifer DC.
	,, *rugosus* DC.
	Crotalaria juncea Linn.
	,, *filipes* Bth.
	Indigofera cordifolia Heyne.
	,, *linifolia* Retz.
	,, *glandulosa* Willd.
	,, *trifoliata* L.
	Psoralea corylifolia Linn.
	Tephrosia purpurea Pers.
	,, *tenuis* Wall.
	Sesbania aculeata Poir.
	Zornia diphylla Pers.
	Phaseolus trilobus Ait.
	Cassia Kleinii W. & A.
	Acacia arabica Willd.
Cucurbitaceæ	*Coccinia indica* W. & A.
Cactaceæ	*Opuntia elatior.*
Rubiaceæ	*Spermacoce stricta* L. f.
	,, *hispida* L.
	Oldenlandia aspera DC.
	Anotis Montholoni HK. f.
Compositæ	*Pulicaria Wightiana* Clke.
	Lagasca mollis Cav.
	Glossocardia linearifolia Cass.
	Vicoa auriculata Cass.
	Tricholepis radicans DC.

Compositæ	*Vernonia cinerea* Less.
	Cæsulia axillaris R.
	Launœa nudicaulis H. f.
	Tridax procumbens Linn.
Apocynaceæ	*Vinca pusilla* Murr.
Asclepiadaceæ	*Calatropis gigantea* Br.
	Dæmia extensa Br.
Gentianaceæ	*Canscora decurrens* Dal.
	Erythraea Roxburghii Don.
Boraginaceæ	*Heliotropium ovalifolium* Forsk.
	Trichodesma indicum Br.
Convolvulaceæ	*Evolvulus elsinoides* Linn.
	Ipomea pes-tigridis L.
Scrophulariaceæ	*Striga lutea* Lour.
	,, *densiflora* Bth.
	Sopubia delphinifolia Don.
Acanthaceæ	*Lepidagathis cristata* Willd.
	Justicia diffusa Willd.
	,, *quinqueangularis* Koen
	Andrographis echioides Nees.
	Ruellia patula Jacq.
Verbenaceæ	*Lippia nodiflora* Rich.
	Lantana camara L.
Labiatæ	*Leucas longifolia* Bth.
	Lavandula Burmanni Bth.
	Orthosiphon tomentosa Bth.
Nyctaginaceææ	*Boerhaavia diffusa* L.
Amarantaceæ	*Digera arvensis* Forsk.
	Celosia argentea L.
Euphorbiaceæ	*Euphorbia coccinia* Roth.
	,, *hypericifolia* L.
	,, *geniculata* Ort.
	,, *pilulifera* L.
	Acalypha malabarica Muell.
	Phyllanthus maderaspatensis L.
	Fluggea microcarpa Bl.
Liliaceæ	*Chlorophytum tuberosum* Bak.
	Asparagus racemosus Willd.
	Iphigenia indica Gray.
	Scilla indica Bak.
	Asphodelus tenuifolius Cav.
Commelinaceæ	*Cyanotis tuberosa* Schult.
	,, *fasciculata* Schult.
	Commelina Forskalœi Vahl.
Cyperaceæ	*Kyllinga triceps* Rottb.
	Cyperus rotundus Linn.
	Fimbristylis Woodrowii Clke.
Gramineæ	*Andropogon contortus* Linn.
	,, *Monticola* Schult.
	,, *annulatus* Forsk.
	,, *caricosus* Linn.

Andropogon foveolatus Del.
,, *pertusus* Willd.
,, *pumilus* R.
,, *purpureo-sericeus* Hochst.
,, *triticeus* Br.
,, *Schœnanthus* L.
Pennisetum cenchroides Rich.
Iseilema laxum Hack.
,, *Wightii* Anders.
,, *anthephoroides* Hack.
Ischœmum laxum Br.
,, *sulcatum* Hack.
,, *pilosum* Hack.
Panicum colonum L.
,, *Isachne* Roth.
,, *javanicum* Poir.
Tricholœna rosea
Polytoca barbata Stapf.
Thelepogon elegans Roth.
Lophopogon tridentatus Hack.
Apluda varia Hack.
Manisuris granularis L.
Aristida redacta Stapf.
,, *funiculata* Trin.
Gracilea Royleana H. f.
Tripogon Roxburghii Bhide.
,, *Jacquemontii* Stapf.
Cynodon dactylon Pers.
Dinebra arabica Jacq.
Eragrostis tenella R. & S.
,, *major* Host.
Oropetium Thomœm Trin.
Trachys mucronata Pers.

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STUDIES IN GUJARAT COTTONS, PART III. THE *WAGAD* COTTON OF UPPER GUJARAT, KATHIAWAD AND KUTCH.

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I. INTRODUCTION.

In former memoirs on the cottons in Gujarat[1], one of the present authors has described the various types of cotton which are grown in this part of Western India, and given a detailed account of two of the three main varieties of *Gossypium herbaceum* cultivated there. These two varieties are the *Goghari* characterized in all its strains by roughness, shortness of staple and high ginning percentage, and the *Broach deshi*, some of whose strains form the highest quality of staple cotton produced in India, cultivated in South Gujarat. This latter type (*Broach deshi*) also includes the somewhat inferior but still good strains grown further north in the Broach district and the Baroda State, and forms with some admixture of the *Goghari* type the bulk of the cotton marketed under the name *Broach*.

North of the area of what is technically known as "Broach Cotton" there lies a very large area producing cotton known on the market as *Dhollcras* which includes almost the whole of Northern Gujarat, Kathiawad and Kutch, which consists of three cotton types known locally as *Lalio*, *Wagad* and *Mathio*. It is with the second of these that the present memoir deals, but before going into

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[1] M. L. Patel. Studies in Gujarat Cottons, Part I. *Mem. Dept. Agri. India. Bot. Ser.*, Vol. [illegible] No. 4.

M. L. Patel. Studies in Gujarat Cottons, Part II. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. X No. 5.

details with regard to it, it will be necessary to give some account of the *Dholleras* cotton as a whole and the area where it is grown.

Dholleras cotton. The type of cotton known as *Dholleras* is grown on an area varying from two to two and half million acres a year, and the yield is estimated by the [1]Indian Department of Statistics from four to six hundred thousand Indian bales of cotton. The actual areas reported in the last three years are as follows :—

	Acres
1922-23	2,014,000
1923-24	2,127,000
1924-25	2,476,000

It will thus be seen that *Dholleras* form one of the most extensively cultivated commercial types of Indian cotton, standing only after *Oomras* and *Bengals*.

This area includes a stretch of country which comprises the whole of Kutch, the whole of Kathiawad, and a portion of Northern Gujarat extending on the east to the boundary of the Ahmedabad district, and the Sabarmati river with a portion of the Cambay State. Beyond this line the cotton rather classes with the *Broach* cotton of the more southern portions of Gujarat.

Dholleras cotton, however, always was a term which included several quite distinct varieties, all, however, belonging to *Gossypium herbaceum*, but the complexity has been increased in relatively recent years by the gradual extension of what is known as *Mathio* cotton, which is an introduced type of *Gossypium neglectum.* As grown at present, therefore, the commercial *Dholleras* is a name which may include cotton of very different quality, from the very inferior *Mathio*, which would class with Khandesh cotton, to the very high quality *Wagad* as grown on the one hand round Viramgam, and on the other in Northern and Western Kathiawad and Kutch. It may be stated, however, that as marketed at present about seventy-five per cent. of the *Dholleras* cotton belongs to the superior *Wagad* type, which is exclusively grown in the Wadhwan, Dhrangadra, Morvi and Kutch States, and in the whole of the Viramgam Taluk of the Ahmedabad District. We may, in fact, look upon the *Wagad* type as being the essential constituent of *Dholleras*, and class the other kinds present (*Lalio* or *Broach deshi* and *Mathio*), as impurities which have crept in owing to certain circumstances of climate and soil and to certain commercial considerations.

Before proceeding to a detailed consideration of the *Wagad* cotton which thus forms the essential constituent of the commercial *Dholleras* a few words may be said as to the distribution of the other constituents. The *Mathio* or Khandesh cotton is said to have been introduced about the time of the famine of 1899-1900, and at once became popular in certain areas, firstly because it grew and ripened much more rapidly and hence was on the market long before the other types were

[1] *Indian Trade Journal*, Feb. 19 and 21, 1925.

plucked, and was thus in no danger from frost ; secondly, it has a high ginning percentage, and thirdly it could be mixed with the genuine *Dholleras* types, such mixing gradually coming to take place on a large scale.

It did not penetrate to an appreciable extent except in certain parts of the Dhandhuka and Gogha taluks of the Ahmedabad District, and the south-western part of Jhalawar in Kathiawad. It is unfortunate that the port which gave its name to *Dholleras* cotton lies in the Dhandhuka taluk, and the area round this place now grows cotton which can hardly properly class with it at all. It should be remembered, however, that even in the palmist days of the port, *Dholleras* cotton was so named, not becuase it was grown round *Dholleras*, but because this was the port through which it reached the market.

The *Lalio* or *Broach deshi* and *Goghari* mixture which forms the second constituent of the *Dh lleras* cotton is found only to an important extent in the south-eastern corner of Kathiawad, in the extreme southern parts of the Ahmedabad District, and in the Sanand and Daskroi taluks of the same district. The *Lalio* lint is of the same general character as that of the *Wagad* type though somewhat weaker, and its presence does not modify and injure the general quality of the *Dholleras* as does the presence of *Mathio.*

II. WAGAD COTTON.

1. History of *Wagad* cotton.

Wagad cotton takes its name either from a tract known as *Wagad* in Kutch or from a group of villages with this name in the Dhandhuka taluk of Ahmedabad. Whether either of these represents the locality where it was originally grown, or whether it was introduced there first from Mesopotamia or Turkey, cannot be said with certainty. But it is certain that a type of *Gossypium herbaceum*, which very closely resembles the *Wagad* cotton, is now grown in Turkey and in Turkestan and is also stated to occur in Mesopotamia. One name of the variety, particularly in Kathiawad, is *Sakalio*, and this recalls the fact that the best quality of this kind of cotton is grown in the Sakaria valley in Turkey in Asia.[1] As grown there it has a staple of $\frac{7}{8}$ inch and has a good colour. An equally probable, or even more proprobable, explanation of the term *Sakalio* is, however, that it means the cotton reaped with *Kalas* or pods, instead of that in which the seed cotton is itself taken from the plant.

We have recently been favoured with some notes on the *Wagad* cotton as grown in Asiatic Turkey[2], and of these we may quote the fact that the cotton is sown in or before April, and is reaped from the middle of October onward. In certain moun-

[1] *Manchester Guardian Commercial,* Feb. 12, 1925.
[2] By the kindness of Mr. N. Husni of Manchester through Dr. H. H. Mann.

tainous district in Asia Minor early frost does appear, but this cotton is hardy enough to resist it, whereas cotton from American seed unless maturing very early does badly on this account.

As regards the *Wagad* cotton said to be grown in Mesopotamia the author received seed from Ahwaz and Shiraz said to be of this type. When grown, however, it showed few, if any, of the peculiarities of *Wagad* cotton, and in its most characteristic feature, the non-opening of the bolls, it behaved in an entirely different manner. The staple was also inferior to the usual *Wagad* cotton though its "feel" was better. The plants seemed, in fact, more like a variety of *Gossypium indicum.*

2. Characteristics of *Wagad* cotton.

Wagad cotton (*Wagadia, Dhumad, Sakalio, Dabalio*) is a small branched bush, usually standing eighteen to thirty inches high under normal cultivators' field conditions, and is much less hairy than *Broach deshi.* The young stems, petioles, etc., are thickly covered with simple hairs. Stellate hairs are numerous on the young leaves and few on the older leaves which are almost glabrous and have a shining oily appearance. The leaves are three to five lobed, cordate, half segmented or less. The lobes are ovate to broad ovate constricted at the base, the lobes of the leaves on the younger branches are broad obtuse. The special characteristics of the leaves are (1) their oily appearance, (2) their generally broad lobing, though this character is not universal, and (3) their leathery character.

The spreading habit of the bractioles is seen in all the annual cottons of Gujarat, but is most marked in *Wagad,* where they often begin to spread when the flower is opening.

This is the earliest flowering type of *Gossypium herbaceum,* though the length of time for maturing the bolls is long. The flowers usually appear about ninety to one hundred days after germination, but the bolls require eighty days or more to mature. The flowers are nearly always yellow and long, though the authors have isolated a white flowered type which also has short petals.

The bolls are smooth and usually globose, though occasionally tapering bolls are found. They are usually three celled bolls, though four celled bolls are not uncommon. But the most characteristic feature of the variety is that the bolls do not open when ripe, or open very slightly, and they do not fall off, but adhere firmly to the plant. It is this characteristic of the bolls of *Wagad* cotton which separates the variety and the method of dealing with the crop, from all other types. The bolls are, in fact, reaped in one lot when all are ripe. The seed cotton is extracted by a special operation done at the convenience of the grower or merchant later on. Even if the bolls remain over the monsoon the contents are not affected or spoilt in any way.

The lint is dull white and coarser than *Broach deshi* and on the average is slightly inferior in staple to the latter. The ginning percentage is variable but is usually

a little higher than that of *Broach deshi*, the trade usually expecting to get 33 to 34 per cent.

The seeds are usually large in size, oval in shape with a distinct hook at the top, and are covered with fuzz. They are usually found five to eight per cell.

One of the features by which *Wagad* cotton can be recognized is the low branching character of the plants, and the fact that the stems rapidly become woody. The main stem is generally short and the number of monopodia rather less than in the other types of *Gossypium herbaceum* grown in Gujarat.

From this it will be seen that the special features which distinguish *Wagad* cotton from other types of *Gossypium herbaceum* are the following. They do not all occur in every case, but several of them are always found, and they can be, as a whole, used for recognizing this variety.

(1) The most characteristic feature is the fact that the bolls either do not open at all or only open slightly, when mature.

(2) The round lobed character of the leaves with the oily appearance and leathery texture is a very marked and very general feature.

(3) The low branching habit of the plant, due not only to the shortness of the internodes on the stem, but also to the fact that the lowest branches arise at a lower node than is usual in other Gujarat types of *Gossypium herbaceum*, is a very characteristic feature. The number of monopodia is, however, generally less than with the *Broach deshi* or *Goghari* varieties.

(4) The bolls are characteristically globose, though this feature is not universal.

(5) The seeds are generally larger than with other varieties and with a very marked and characteristic hook at the end (Plate III, 2).

3. The conditions under which *Wagad* cotton is grown.

The area where *Wagad* cotton is grown is almost entire'y an alluvial plain, though there are some hills in both Kutch and Kathiawad. The alluvium in this area is, however, entirely of a different character from that found in Lower Gujarat and described in the author's previous memoir. Being derived from the granitic and gneissic rocks of Rajputana and Central India, it takes much more the character of a river silt, but gives the impression of having been deposited either on the edge of the sea or in brackish water, for, almost all over, the soil is somewhat saltish, a feature which becomes very marked in Northern Kathiawad and Kutch. The sticky character of the black soils of Lower Gujarat is largely absent, and while the land is often clayey, it never becomes slimy in the same way as the soils of Surat.

The following analysis of typical *Wagad* cotton growing soils from two centres in the tract will indicate some of the features which are most characteristic. The

surface soil is from the surface to eight or nine inches deep, the subsoil represents the layer below this. The samples taken are (1) from Bavla (Dholka Taluk) in the southern part of the Ahmedabad District, and (2) from Viramgam, a typical centre in the northern portion of the same district. The analysis of the former were made by Leather at Pusa, the latter by Sahasrabuddhe at Poona.

——	Surface soil	Subsoil
BAVLA		
Mechanical analysis	Per cent.	Per cent.
1. Sand (Particles over 0·032 mm. diameter)	70·90	52·5
2. Fine sand (Particles from 0·016 to 0·032 mm.)	13·10	20·0
3. Coarse silt (Particles from 0·006 to 0·016 mm.)	8·00	15·2
4. Medium silt (Particles from 0·004 to 0·006 mm.)	5·10	7·9
5. Fine silt (Particles from 0·002 to 0·004 mm.)	1·90	2·0
6. Clay (Particles under 0·002 mm.)	1·00	2·4
VIRAMGAM		
1. Coarse sand (Particles over 0·16 mm. diameter)	20·0	..
2. Fine sand (Particles from 0·07 to 0·016 mm.)	11·0	..
3. Coarse silt (Particles from 0·03 to 0·07 mm.)	12·0	..
4. Medium silt (Particles from 0·01 to 0·03 mm.)	14·9	..
5. Finest sand and clay (Particles below 0 01 mm.)	43·6	..
BAVLA		
Chemical analysis		
Organic matter and combined water	2·48	2·20
Lime (CaO)	1·18	0·94
Available potash (K_2O)	0·045	0·040
Available phosphoric acid (P_2O_5)	0·144	0·0032

Despite a different basis for classifying the soil particles, the mechanical analysis well illustrates the extremes which are found in the alluvial cotton growing soil in this area. The Bavla soils represent very sandy land, but one where both *Wagad* and *Lalio* cotton are very successful; the Viramgam soil is from a heavy clay tract, but one where *Wagad* cotton only is equally successful. From the chemical point of view the soil contains a fair proportion of lime, and the available potash and phosphoric acid (determined by Dyer's method) show a soil well provided with these constituents. The organic matter is low, as is always the case in these semi-arid regions.

The authors are not able to present analysis showing the amount of salt in these soils, but the following figures of the amount of salt contained in well water from a

well twenty-five deep at Viramgam show something of the brackish character of the land from which it is derived.

	Viramgam well water Parts per 100,000.
Calcium carbonate	20·0
Magnesium carbonate	34·0
Magnesium sulphate	38·0
Magnesium chloride	19·0
Sodium carbonate	7·5
Sodium sulphate	36·0
Sodium chloride	49·0
Total soluble salts	270·0

The characteristic soil for *Wagad* cotton is then an alluvial silt of a heavy or light character, with a fair content of lime and which is distinctly salty.

Rainfall in the Wagad cotton area. The climate is also characteristic and represents as a whole the most dry tract in India where cotton is habitually grown without irrigation. This is especially the case in North and West Kathiawad and Kutch. The actual average rainfall for five typical stations in the *Wagad* cotton area is shown below :—

	Viramgam (N. Ahmedabad)	Dholka (S. Ahmedabad)	Morvi (N. Kathiawad)	Porbunder (W. Kathiawad)	Bhuj (Kutch)
	inches	inches	inches	inches	inches
January	0·04	0 05	0·02	0·05	0·07
February	0·11	0·13	0·09	0·10	0·15
March	0·08	0·04	0·07	0·09	0·10
April	0·01	0·02	0·00	0·00	0·08
May	0·50	0·47	0·13	0·07	0·09
June	3·23	4·01	2·72	4·41	1·52
July	10·81	12·34	9·78	7·62	6·13
August	6·48	7·07	5·51	4·46	3·15
September	3·70	5·06	2·20	2·16	1·77
October	0·41	0·67	0·51	0·23	0·54
November	0·22	0·23	0·11	0·38	0·08
December	0·03	0·03	0·02	0·06	0·04
TOTAL	25·62	30·12	21·16	19·63	13·72
Total (June to October)	25·31	29·23	20·72	18·88	13·11

The general features are obvious. The rainfall is for all practical purposes limited to the months from June to October, and as one proceeds to the west the actual quantity received rapidly goes down. The rainfall in Bhuj, the centre of Kutch, is about the limit for the successful growth of cotton without irrigation.

These average figures (for periods which vary from thirty to fifty years) are important, but do not represent the whole of the case. The question of the extent of variation from year to year is equally important, and we have figures which show this for fifty years in two typical centres in the Ahmedabad District where *Wagad* cotton is grown.

Ranges of total rainfall	Viramgam	Dholka
	Number of years	Number of years
Below 11 inches	6	3
11 to 14 inches	1	2
14 „ 17 „	2	3
17 „ 20 „	3	0
20 „ 23 „	4	3
23 „ 26 „	5	3
26 „ 29 „	13	9
Over 29 „	16	27
Total	50	50

Now when the rainfall is below 14 inches in the Ahmedabad District, the experience has been that the official records show always a crop below 50 per cent. of the normal, and usually 33 per cent. of the normal or less. In other words, the cotton crop in the area in question with such a rainfall is almost a failure. Over this amount (14 inches) the crop seems to have usually enough rain to bring it normally to maturity, and rain of over 20 inches does not seem to be required provided the distribution is satisfactory.

The distribution has, however, varied very much, and the following table gives some idea as to the extent of such variation month by month.

Number of occurrences

Range of monthly rainfall	Viramgam				Dholka			
	June	July	August	September	June	July	August	September
Under 4 inches	37	10	14	31	27	6	18	27
4 to 8 „	9	7	22	10	17	8	15	13
8 to 12 „	4	14	6	6	5	13	8	5
12 to 16 „	..	11	5	3	1	12	7	2
16 to 20 „	..	3	2	1	..	2	1	2
Over 20 „	..	5	1	..	..	9	1	1

The most frequent rainfall in Viramgam and Dholka is therefore below 4 inches in June, between 8 and 12 inches in both in July, between 4 and 8 in Viramgam in August, while in Dholka it is most frequently under 8 inches in that month. In September both the places show a normal rainfall of under 8 inches with a somewhat larger rainfall in Dholka than in Viramgam.

Temperature in the Wagad cotton area. The following table shows for each month at Surat and Ahmedabad (1) the average maximum shade temperature and (2) the average minimum shade temperature. Surat is included in order to enable the conditions under which *Broach deshi* cotton is best grown to be compared with a typical climate for *Wagad* cotton.

	Surat (*Broach deshi* cotton)		Ahmedabad (*Wagad* cotton)	
	Average maximum shade temperature °F	Average minimum shade temperature °F	Average maximum shade temperature °F	Average minimum shade temperature °F
January	86·6	57·7	84·9	57·7
February	88·3	59·4	87·7	59·5
March	95·7	66·3	96·9	67·2
April	99·3	73·4	104·2	74·4
May	96·9	78·7	107·4	79·1
June	93·0	79·5	101·3	80·8
July	87·4	78·1	93·1	78·5
August	86·7	76·9	90·0	76·8
September	88·7	75·7	92·9	76·0
October	94·0	71·9	97·3	72·4
November	91·8	64·5	92·8	65·5
December	87·8	59·0	86·4	59·2

The cotton is sown normally in July, and the crop is reaped in March and April. The period of most rapid development of the plants is in October after the rains are practically over. This compares very closely in point of temperature with the conditions at Surat, except that the maximum temperature during the early part of the growth, and even upto November is higher in the *Wagad* cotton growing regions and lower during the succeeding cold weather months. The temperatures are very high (always over 100°F) before the main part of the cotton is reaped. The mean temperature during the growth of the plants is higher than at Surat and than in almost all other cotton growing centres. The mean temperature during flowering and boll production is a little lower than at Surat, but still distinctly higher than most other cotton growing centres.

Humidity. A characteristic feature of the *Wagad* cotton growing areas is the low humidity of the atmosphere during a large part of the cotton growing season.

The actual humidity for Surat and for Ahmedabad for these months are as follows :—

Month	Humidity	
	Surat	Ahmedabad
	Per cent.	Per cent.
June	73	68
July	78	76
August	79	83
September	78	76
October	57	56
November	57	45
December	59	49

The feature of these figures is the exceeding dryness of the atmosphere during the flowering and bolling period of the cotton. In this matter it is perhaps drier than anywhere else where fair staple cotton is grown without irrigation, and it has been suggested that this may have something to do with the roughness of the *Wagad* cotton. The connection is, however, as yet only a matter of speculation.

Method of growing Wagad cotton. With the soil and climatic conditions which have been described, *Wagad* cotton is grown in the following manner. The normal rotation is that of cotton and *jowar* (*Andropogon sorghum*), but *bajri* (*Pennisetum typhoideum*) is often taken instead of the latter in many parts of Kathiawad. In many areas, however, it has become the custom to grow *Wagad* cotton year after year for three or four years in succession, on the same land,—and only then to take a rotation crop of *jowar*.

The crop is sown at the first available opportunity after the breaking of the monsoon, but whenever there is difficulty in obtaining a proper stand, it is sown successfully as late as September. It is usually drilled in rows from fifteen to twenty-four inches apart by a three to four coulter drill. The seed rate is about fifteen pounds per acre. The general standard of cultivation and of sowing is very much lower than in the areas of Surat and Broach, where *Broach deshi* cotton is sown. Cattle manure is not usually available as it forms the chief fuel over most of these areas, but where it is available it is used almost entirely for the cotton crop. No artificial manures are used for the crop.

The land is hoed by a blade harrow during its early growth, and finally weeded by hand (pickaxes) in September. The crop is never thinned.

In a normal year the crop begins to flower at the end of October, and is harvested at the beginning of April, the whole being taken at one picking. The yield which is expected by the people is about 300 lb. of seed cotton per acre equal to about 100 lb. of clean cotton. The cotton bolls are pulled whole, and the seed cotton extracted later. One hundred pounds of ripened bolls will give 70 to 75 pounds of seed cotton.

III. THE HEREDITARY NATURE AND THE VARIATION OF CERTAIN CHARACTERS IN WAGAD COTTON.

The main results which have been obtained regarding the variation which occurs in the characters of this cotton have been secured by the study of a limited number of strains isolated from a mixed population obtained from several localities in the Ahmedabad District (Sanand, Viramgam, Bavla), and in Kathiawad (Mandal). They have now been under study since 1917.

(*a*) The number of monopodia.

The number of monopodia in a plant determines in a very large measure its growing character, and hence a study of the extent of variation in this matter, and as to whether it is hereditary or no is of great importance. In *Broach deshi* cotton one of the authors has shown[1] the high degree to which this character remains constant in the same strain from year to year.

Using the same criterion of the hereditary character of any feature of a strain which the author has previously employed, namely, the constant relationship of the character in two or more strains in successive years, the number of the monopodia has been determined in a series of at least one hundred plants in four different strains in 1921-22, 1922-23, 1923-24 and 1924-25. The results which follow show the mean value of the number of monopodia in each strain in each year.

Number of monopodia.

(Mean Value).

Strain	1921-22	1922-23	1923-24	1924-25
No. 8	6·6	3·2	3·1	2·5
White Flower	7·3	3·9	3·5	..
No. 14	7·9	4·5	5·0	5·0
No. 4	8·1	4·3	4·8	3·2

These figures show the very considerable differences in number of monopodia obtained by growing under different conditions. The cultivation in 1921-22 was made at an experimental area near Sanand, which had to be abandoned for other reasons; in the remaining years the plants were grown near Viramgam on much heavier soil. In the latter place, the number of monopodia has remained fairly constant for each strain.

[1] Studies in Gujarat Cottons, Part II. *Mem. Dept. Agri. India, Bot. Ser.* Vol. XII, No. 5, p. 197.

The variation in the different pure strains is also very considerable, the average for the three seasons at Viramgam varying from 2·9 per plant with strain No. 8 to 4·8 with strain No. 14.

Within each pure strain the number varies from year to year, and in each year as is shown by the frequency curves of the number of monopodia on one hundred plants in strain No. 14, and White Flower (Figs. 1 and 2), the variability is considerably different in the years quoted, thus in 1923-24 the variation was particularly narrow. But the point which is clearly shown by the results given is that wherever

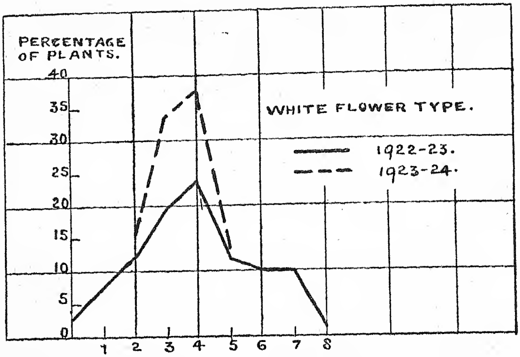


FIG. 1. Number of monopodia.

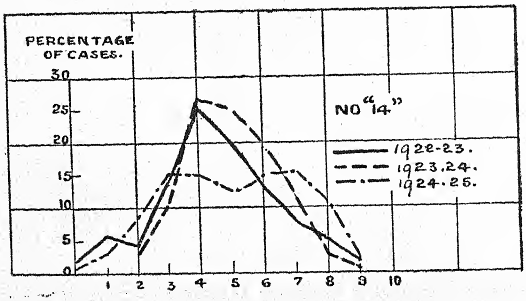


FIG. 2. Number of monopodia.

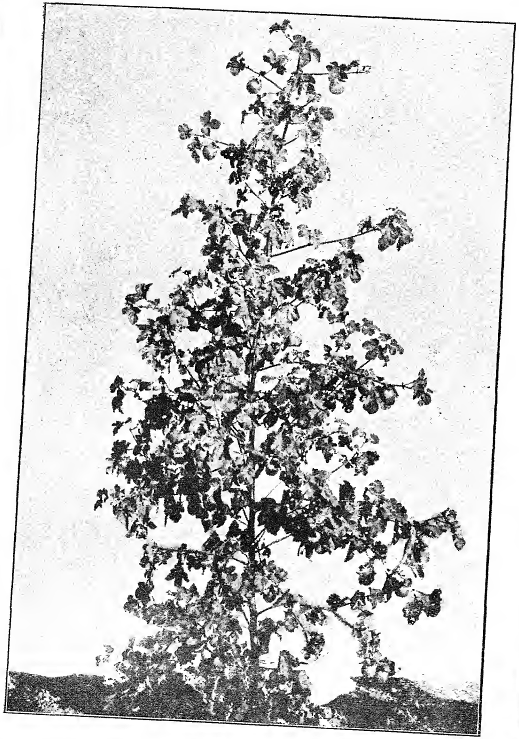


Fig. 1.
Wagad strain "8" least number of monopodia, *i.e.*, erect in habit of growth though with short internodes.

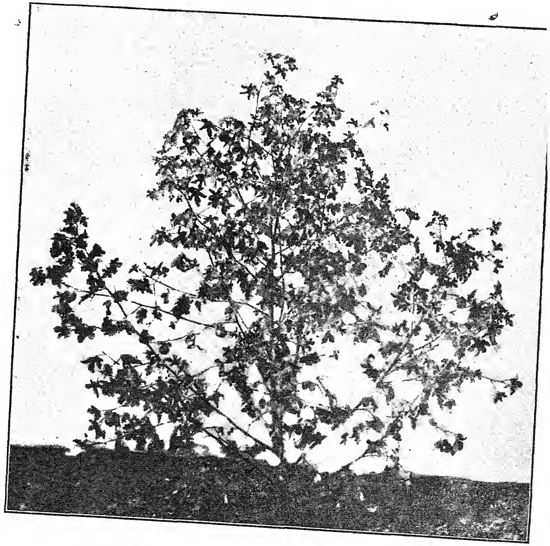


Fig. 2.
Wagad strain "14" larger number of long spreading monopodia and Axillaries.

grown and whatever the conditions, the order in which the strains stand in respect to the number of monopodia is the same. The strain No. 14 has always the most, and Strain No. 8 has always the fewest. The differences can very clearly be seen in Plate No. I. In other words as with other varieties, the character of possessing a large or a small number of monopodial branches is heriditary.

(*b*) The position of the first fruiting branch.

The importance of the point in a growing cotton plant where the first fruiting branch (sympodium) arises has been shown in the author's previous memoir. This determines, in fact, the earliest flowering, and so has something at least to do with the earliness or lateness of a variety. But the character is exceedingly variable, and it is only by a close comparison of strains grown side by side, under precisely the same conditions, in a series of years, that the hereditary nature of the character can be determined. It is a character which varies widely with the closeness of planting, with the dryness or wetness of the season, as well as with the strain, while under any given set of conditions it is extremely variable within a strain.

Now the matter is of special importance with *Wagad* cotton owing to the system of growing the plants, thick in the rows, and often very late in the season,—for this means that a considerable proportion of the yield is obtained from pods growing on primary sympodia. It is also important because most of the early formed flowers in this variety are successful, while there is a large proportion of shedding in the later formed flowers.

For four strains the modal value of the node from which the first primary fruiting branch arises is as follows :—

Position of first fruiting branch.

(Modal Value).

Strain	1921-22	1922-23	1923-24	1924-25
	Node number	Node number	Node number	Node number
"8"	12	11 & 12	6 & 7	10 & 11
"White Flower" .	11	11	7	..
"14"	15	14 & 15	8 & 9	15
"12"	14	13 & 14	9	14 & 15

The variability in a single season was great, and the coefficient of variability in each strain was over 10 in the first two years, between 12 and 13½ in 1923-24, and over 14 in 1924-25. But even allowing for all this, it is seen that the strains where the first fruiting branch arises at a higher node than the others in one year possess the same character in the other years of very different character.

The figures show further the remarkable effect of a dry season on this character. The year 1923-24 was a very dry one, and in this year the first fruiting branch arose at a very much lower node than in the other years. In this season, in fact, the plants approached the American types in this respect, for under their own conditions the latter produce the first sympodium from the fifth or sixth node of the growth of the main stem.

(c) The shedding of flower buds.

In every type and variety of cotton there is a large proportion of the flower buds formed, which never produce flowers. The loss is particularly great in Gujarat where in *Broach deshi* cotton it has been found to vary from 58 to 72 per cent. In American cotton it seems to vary between 14 to 17 per cent, and in Sea Island cotton it may rise to from 40 to 50 per cent. Though, due to many causes such as insect attack, unsuitable cultivation, sudden change in the moisture content of the soil, or drying up of the conditions, the environment greatly influences the amount of shedding, yet there seems, from the evidence in hand, to be a heriditary character involved, and strains *do* seem to have a varying capacity to mature the flower buds which they form[1]. This was found to be the case in various strains of *Broach deshi* cotton and the figures now to be presented show the position in types of *Wagad* cotton.

Percentage of flower buds forming flowers.

Strain	1922-23	1923-24	1924-25
	Per cent.	Per cent.	Per cent.
"White Flower"	38·8	26·3	..
"4"	37·1	33·8	27·2
"8"	32·5	33·6	23·6
"12"	38·6	26·4	23·4
"14"	37·2	31·8	24·1

From these figures as they stand any direct connection between the percentage of success of flower buds into flowers seems very slight. The strain with the greatest success in one year (*e.g.*, No. "12" in 1922-23) becomes the lowest in another (*e.g.*, No. "12" in 1924-25). It is evident that the matter requires a closer analysis. Let us, therefore, take the figures for success in the early part of the season, that is

[1] A discussion of the literature on this Subject will be found in Studies in Gujarat Cottons, Part II, page 231.

to say, during the first months of flowering instead of during the whole season. Then we have the following figures :—

Percentage of flower buds forming flowers.

Strain	1922-23	1923-24	1924-25
	Per cent.	Per cent.	Per cent.
" White Flower "	42·5	42·1	..
" 4 "	36·5	31·6	23·7
" 8 "	33·2	45·4	17·6
" 12 "	38·5	40·2	11·5
" 14 "	35·0	43·2	12·8

In the first two years for which figures are given the success in the early part of the flowering season was much greater than in the latter part, but this is certainly not the case in 1924-25 when there was a generally very much more luxuriant growth of the plants. In fact, these figures, no more than the last, give no evidence of the directly hereditary character of the shedding of flower buds in these strains. If it exists, it is obviously swamped by other factors which vary widely in their effect from season to season. But if we take the proportion between the success in the early part of the season and that in the whole season a specific character for each strain seems to be somewhat clearly indicated. The figures are as follows :—

Percentage of total success of flower buds to early success (100).

Strain	1922-23	1923-24	1924-25
	Per cent.	Per cent.	Per cent.
" White Flower "	91·2	59·0	..
" 4 "	101·6	65·0	114·5
" 8 "	97·9	74·0	133·4
" 12 "	100·0	65·6	203·1
" 14 "	106·3	73·8	188·9

This table throws a little light on the matter, but does not, by any means, clear it up. There certainly seems a tendency for certain types to have a large proportion of early success (White Flower, and less clearly " 4 " and " 8 ") and of others to have a large amount of late success among flower buds (" 14 "). But except in the case of White Flower where the success of the early flower buds is large in both years as compared with that in other strains, there is not any very clear indication in this direction.

In the author's previous memoir it was shown that if we take the ratio of the number of flower buds to the number of nodes of growth in vegetative branches, this relationship of the reproductive to the vegetative growth of the plant seems to be correlated with the amount of success in the flower buds formed on the plant. We may see now how far this is the case in the strains of *Wagad* cotton now under discussion.

Ratio of flower buds to nodes of growth.

Strain	1922-23	1923-24	1924-25
" White Flower "	0·93	1·59	..
" 4 "	0·77	1·22	0·97
" 8 "	0·91	1·12	0·93
" 12 "	0·64	1·00	0·64
" 14 "	0·72	0·99	0·64

Though the results are not very clear, yet they do suggest that a large amount of vegetative growth in the plant tends to be connected with a low proportion of success in the flower buds formed in the early part of the season. This does not apply completely in every case, but there is sufficient indication to be very suggestive. If true, it means that a strong growing type of plant is likely to be a late plant, and this result, if generally applicable, would be of great importance.

The general result of this discussion is therefore that unlike what was found in *Broach deshi* and other types of cotton the authors have studied, they have not been able to establish a direct hereditary correlation between pure strains and success of flower buds, for any such correlation is swamped by other, probably environmental factors.

On the other hand, there is evidence of a connection in *Wagad* cotton (as in *Broach deshi* cotton) between vegetative luxuriance and loss of flower buds, though the connection as yet is not very clear. If a vegetatively luxuriant type is necessarily a late type, as would appear to follow, the result may be of considerable im-

portance. The results given, it is recognised, only suggest this, and many more data will be needed in order to establish the point.

One point of considerable interest arises in connection with the shedding of flower buds. Is the proportion of shedding affected by the class of branch on which the flowers are borne? The following table shows the records on this point for three years for five pure strains :—

Percentage of success of flower buds.

Kind of branch	Strain "White Flower"	Strain "4"	Strain "8"	Strain "12"	Strain "14"
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
I. From monopodia					
1922-23	29·8	29·7	21·1	34·7	27·1
1923-24	19·6	14·1	17·6	17·6	24·3
1924-25	..	16·2	13·3	13·6	16·6
II. Primary fruiting branches					
1922-23	44·4	42·2	38·4	41·8	42·8
1923-24	29·0	37·6	37·6	32·9	37·7
1924-25	..	30·2	21·5	22·3	21·4
III. From axillary vegetative branches					
1922-23	9·5	31·7	11·4	35·0	27·9
1923-24	21·3	0·0	0·0	14·6	6·9
1924-25	..	30·0	21·2	33·0	35·3

While these figures show on the whole a great proportion of success of buds which develop on the primary fruiting branches,—except perhaps in the season 1924-25 when there was specially luxuriant growth, when the later formed flower buds on the axillary vegetative branches are at least equally successful,—yet they do not reveal very much constancy between the dfferent strains. Strain No. 4 seems to be consistently the most successful, so far as the buds on primary fruiting branches are concerned, but, generally speaking, this further analysis of the position of the buds on the plant does not reveal clearly any hereditary factor, which, if it exists, seems swamped by seasonal conditions.

(*d*) The shedding of flowers and young bolls.

The shedding of potential cotton producing organs is not limited to the flower buds, for there is always a considerable amount of loss of flowers and young bolls. This has been studied by many workers, and has been attributed[1] to root pruning by deep cultivation, to excessive vegetative growth at the flowering period, to heavy rain, to severe drought, to overcrowding of the plants, to insufficient pollination from whatever cause, to insect attack whether by aphis, bollworm, or boll-weevil, to defective nutrition and to a number of other causes.

But there seems to be a variable amount of shedding under perfectly normal conditions, which in many cases seems dependent on the actual strain in cultivation. This was shown to be the case, with *Broach deshi* cotton in the author's previous memoir (*loc cit*), but to be partially masked by seasonal and environmental conditions at Surat. The results now to be given for *Wagad* cotton, seem to show even more clearly the presence of such a hereditary factor.

The actual figures for the loss of flowers and bolls in four years, with the pure strains previously noted were as follows :—

Percentage of ripe bolls to open flowers.

Strain	1921-22	1922-23	1923-24	1924-25
	Per cent.	Per cent	Per cent.	Per cent.
" White Flower "	38·3	34·9	37·6	..
" 4 "	52·4	36·0	41·9	29·1
" 8 "	..	40·8	50·0	31·4
" 12 "	54·0	40·3	48·1	31·4
" 14 "	61·2	38·8	46·6	31·3

It will be seen that the loss is very similar in the first three years quoted to that in *Broach deshi* cotton as grown at Surat, but in 1924-25, the loss was much greater. It is interesting to find this large record of failure in a year of very vigorous vegetative growth. But the relative position of the strains is almost exactly the same in the different years. In 1921-22 when (as previously described) the experiments were done under different conditions. Strain " 14 " gave a larger success than its subsequent performances seem to justify, but apart from this one case, the relative position of the different strains is the same in each year. Thus there seems to be a hereditary factor involved, but it seems a matter of importance to select for general cultivation a strain with high capacity of maturing its bolls.

[1] A discussion of the literature of the subject is given in the author's previous Memoir.

While the question of flower and boll shedding is under consideration it may be noted that the flowers formed at different stages of the season have by no means the same chance of producing successful bolls. This has already been noted with *Broach deshi* cotton grown at Surat, where it was found that the early flowers and the late flowers are very largely lost. Here, with *Wagad* cotton the position is different, and a very high percentage of success in the early part of the flowering season is found. The following are the actual figures in three successive seasons for the different portions of the flowering season :—

Percentage of ripe bolls to open flowers.

Strain	First three weeks of flowering	Fourth week of flowering	Fifth week of flowering	Sixth week of flowering	Seventh week of flowering
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
I. " White Flower "					
1922-23	57·4	17·2	14·3	7·1	*Nil*
1923-24	59·6	38·6	16·9	7·7	11·1
II. " 4 "					
1922-23	71·0	45·2	21·9	3·8	4·1
1923-24	66·2	27·7	10·8	11·1	0·0
1924-25	33·4	59·1	55·8	28·5	5·1
III. " 8 "					
1922-23	85·6	56·6	33·2	15·5	10·8
1923-24 . .	64·8	29·8	21·2	33·3	0·0
1924-25 . .	95·7		68·5	53·5	10·2
IV. " 12 "					
1922-23 . . .	73·0	52·1	23·8	14·8	7·9
1923-24	72·1	42·6	21·8	26·1	14·3
1924-25	65·0		64·7	53·3	19·5
I. " 14 "					
1922-23	76·5	58·0	24·0	14·6	16·9
1923-24	65·7	28·0	9·5	12·5	26·3
1924-25	75·0	..	75·0	66·6	16·0

With one exception the figures show a very high percentage of success with early formed flowers, and the remarkable results between these results and those at Surat with *Broach deshi* cotton is worthy of very much closer study.

The proportion of success of flowers on different classes of branch is shown in the following table:—

Percentage of ripe bolls to open flowers.

Kind of branch	Strain "White Flower"	Strain "4"	Strain "8"	Strain "12"	Strain "14"
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
I. From monopodia					
1922-23	28·6	21·5	21·0	29·3	30·9
1923-24	33·9	26·2	50·0	35·7	44·6
1924-25	..	37·3	26·9	31·5	34·1
II. From primary fruiting branches					
1922-23	36·5	42·7	44·5	47·2	45·5
1923-24	39·8	44·4	50·0	51·6	48·1
1924-25	..	31·4	35·9	43·3	48·4
III. From axillary vegetative Branches					
1922-23	0·0	24·7	11·8	30·9	13·1
1923-24	17·6	0·0	0·0	44·4	0·0
1924-25	..	13·5	9·9	18·4	13·2

It will be seen that, except in the year 1923-24 when the crop was very early, the success of the flowers to mature bolls is in every strain of this type of cotton (except No. 4 in 1924-25) as grown at Viramgam, much greater when borne on the primary fruiting branches. The greater importance of flowering of this type to determine the yield must hence be emphasised as against the conclusions for *Broach deshi* cotton grown at Surat. Attention may perhaps also be called to the success in certain strains only (*e.g.*, No. "12" above) of the flowers borne on axillary vegetative branches.

Before passing from the consideration of this question we may summarise the figures so as to show the total loss by shedding of flower buds, flowers and bolls in

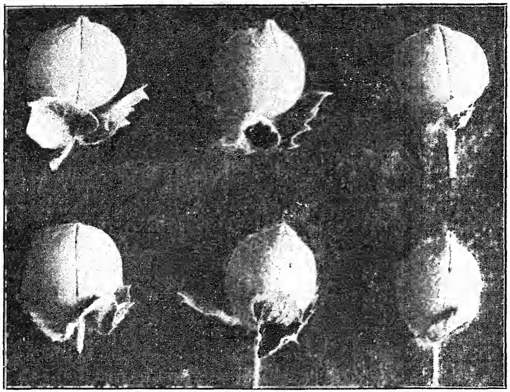


Fig. 1.

Types of bolls in *Wagad* Cotton.

Upper row. 1, Big globose boll of strain "8"; 2, Globose boll with tip of strain "4"; 3, Small globose boll of strain "12".

Lower row. 1, Small globose boll of strain "14"; 2, Tapering boll of strain "Long Boll"; 3, Small and distinct tipped bolls found in "local".

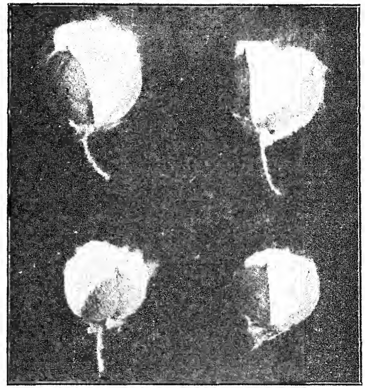


Fig. 2.

Upper row. Bolls of strain "4" showing the wider opening and a distinct tip, thought to be associated with long staple.

Lower row. Bolls of strain "12" showing the narrow opening, with seed cotton less exposed and finally giving cleaner produce.

strains of Wagad cotton grown in the Ahmedabad District. The total percentage of loss has been as follows :—

Total loss by shedding.

(Percentage of bolls to flower buds.)

Strain	1922-23	1923-24	1924-25
	Per cent.	Per cent.	Per cent.
"White Flower"	13·5	10·0	..
"4"	13·4	14·2	7·9
"8"	13·3	16·8	7·4
"12"	15·6	12·7	7·4
"14"	14·4	14·8	7·6

The total loss by shedding is, therefore, at least as high as with *Broach deshi* cotton at Surat, and in certain years like 1924-25 it is much higher and considerably over 90 per cent.

(*e*) THE SHAPE AND SIZE OF THE BOLLS.

It has already been stated that one of the characteristics of *Wagad* cotton is the globose boll, though this feature varies considerably. In Plate II are shown six types which differ distinctly in this feature, and in some cases show a distinctly tapering boll, lower row (Nos. 2 and 3). The bolls also vary much in size, some of the strains isolated being distinctly large boll types, while others are markedly smaller.

We may take the amount of *kapas* per boll,—or rather its reverse, the number of bolls required to furnish one pound of *kapas*,—as a measure of the size of the boll, and this has been determined for each of four selected strains for a series of three years. The figures obtained are shown below :—

Number of bolls per pound of kapas.

Strain	1922-23	1923-24	1924-25
"4"	202	206	181
"8"	197	194	180
"12"	205	242	207·5
"14"	235	242	207

Thus strains Nos. " 4 " and " 8 " furnish bolls of greater size, consistently, and may be termed big bolled strains. No. " 14 " is equally certainly a small bolled strain, and has remained so throughout the period. The relative position of the strains is the same throughout, and hence this character may be considered as hereditary, though the actual size of the bolls in any particular year will vary with the seasonal conditions.

The size of the bolls depends, however, partly at any rate on the proportion of 4-celled bolls produced, and if it can be shown that the large bolled types contain consistently larger proportion of 4-celled bolls the reason for the large bolling character will have been, partly at least, cleared up. The actual proportion of such 4-celled bolls has been determined for the four selected strains in four successive years and proved to be as follows :—

Percentage of 4-celled bolls.

Strain	1921-22	1922-23	1923-24	1924-25
	Per cent.	Per cent.	Per cent.	Per cent.
" 4 "	5·0	11·0	7·5	8·0
" 8 "	2·0	8·5	1·0	2·0
" 12 "	1·0	4·5	1·5	3·5
" 14 "	2·0	3·0	0·5	3·5

These results are not entirely consistent, but they do show clearly, every year that the typically small bolled *Wagad* strain (No. " 14 ") has always a small proportion of 4-celled bolls. Equally certainly the typically large bolled type No. " 4 " has always a large proportion of 4-celled bolls. While it is not clear *how far* the largeness of the bolls is the result of the frequency of 4-celled bolls, it seems probable that it is one of the influences which determine this feature, and that it is hereditary.

The shape of the bolls also appears to be hereditary, but it is very difficult to get a single figure which represents the shape. Measurements have been taken (1) of the total length of the boll from the gland to the extreme end of the tip and (2) the greatest diameter of the boll. The results for the four typical strains in four successive years are shown in the following two tables :—

I. Average length of the bolls from gland to tip.

Strain	1921-22	1922-23	1923-24	1924-25
	cm.	cm.	cm.	cm.
" 4 "	3·1	2·8	2·8	2·8
" 8 "	2·9	2·6	2·7	2·8
" 12 "	2·7	2·5	2·5	2·7
" 14 "	2·7	2·5	2·4	2·6

II. Average diameter of the bolls (Maximum diameter).

Strain	1921-22	1922-23	1923-24	1924-25
	cm.	cm.	cm.	cm.
"4"	2·7	2·6	2·6	2·7
"8"	2·7	2·6	2·5	2·7
"12"	2·6	2·5	2·4	2·6
"14"	2·6	2·6	2·4	2·6

These figures show at once how extremely globose are these bolls. The boll index (the relation of maximum diameter to length) in the present variety of cotton is very high, amounting with the different strains in 1924-25 to 95·1 for strain "4" to 99·0 for Strain "8", to 97·8 for Strain "12" and to 99·6 for strain "14." This compares with the following figures (for 1921-22 only) for different strains of *Broach deshi* cotton :—

Strain	Average length of bolls from gland to tip	Average diameter of the bolls (maximum diameter)	Boll index
"B. 1"	2·9	2·4	82·7
"C. 1"	3·0	2·4	80·0
"Selection II"	3·1	2·6	83·9
"1 A Cylindrical boll"	3·1	2·5	80·7
"1027 A. L. F."	3·4	2·6	76·4

The *Wagad* strain No. 4 above is very marked on account of its possession of a longer tip (Plate II), and this is so distinct that since the introduction of these strains into cultivation it has become a recognised character, as indicating a high staple cotton. There is no evidence, however, at present of any general correlation between the length of the tip and the staple of the cotton in *Wagad* types.

Attention may be called to the fact that while globose bolls are fairly characteristic of *Wagad* cottons, tapering bolls do occur, and two of these are illustrated. (Nos. 2 and 3) in Plate II, Fig. I, Lower row.

(*f*) Proportion of bolls borne on primary flowering branches.

In a former memoir on *Goghari* cotton, the author has shown that the faculty of bearing a large proportion of the crop on the primary fruiting branches is here-

ditary. In selected *Broach deshi* types little difference was found in this particular. But among *Wagad* cotton the differences are considerable, and again the character appears to be hereditary. If so, it is an important factor, because by the use of strains differing in this particular, types suited to widely separated climatic conditions may be obtained. Of the selected strains which have been under detailed examination, the figures obtained in these successive years are as follows :—

Proportion of crop on primary fruiting branches.

Strain.	1922-23	1923-24	1924-25
	Per cent.	Per cent.	Per cent.
" White Flower "	81·7	85·1	..
" 8 "	83·8	94·7	88·6
" 12 "	72·9	78·2	65·1
" 14 "	80·6	82·0	68·9

The results are quite consistent. No. " 8 " is a strain which from year to year bears a larger proportion of its fruit on primary fruiting branches, while No. " 12 " is a type in which bearing on other types of branch is much more important.

(*g*) Length of the seed hairs (Staple).

We now come to perhaps the most important character in any cotton, namely, the staple of the lint which it produces. It has already been noted that the staple of *Wagad* cotton in general is slightly inferior to that of the best strains of *Broach deshi* cotton. We have now to study how far in the pure material which has been isolated, the staple varies, first from strain to strain, and then within the strain itself. In making determinations of the length of the seed hairs, the hairs of one hundred seeds have usually been measured, all the seeds of half a cell being taken. The measurements have always been taken at the tip, the middle and the base of each seed except in 1924-25 when they were only taken at the middle of the seed.

The actual results of the measurements of the length of the lint hairs of different strains in different years with *Wagad* cotton are as follows :—

Average length of seed hairs.

Strain	1921-22			1922-23			1923-24			1924-25
	Tip	Middle	Base	Tip	Middle	Base	Tip	Middle	Base	Middle
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
" White Flower "	18	21	19	17	20	19	16	20	18	20
" 4 " . . .	19	22	20	18	21	20	17	21	20	21
" 8 " . . .	17	21	18	17	20	19	16	20	19	20
" 12 " . .	17	21	19	16	20	19	16	20	18	19
" 14 " . .	18	21	19	15	18	18	16	20	19	19

There are thus very wide variations from season to season in the staple of the cotton, produced by one and the same strain, and some strains show a much greater variability than others. The strain No. "4" has, however, consistently stood above all the others, and if we take the length of the seed hairs at the middle as characteristic, the remainder have differed very little except in 1922-23 when No. "14" lost its staple more than any of the others.

In this connection a matter of much interest was as to how far the staple varies in the produce of different parts of the season. This was determined by measuring the lint on the middle of the seed from flowers opening in different weeks of the flowering season. The results are as follows :—

Length of staple of cotton from middle of seed.

Week of flowering.

Strain	1	2	3	4	5	6	7
	mm.	mm.	mm.	mm.	mm.	mm.	mm.
				1922-23.			
"White Flower" . .	22	22	20	21	20	..	..
"4"	23	24	23	23	22	..	..
"8"	21	22	23	21	21	20	20
"12"	22	22	21	21	20	20	..
"14"	20	20	19	20	19	20	19
				1923-24.			
"White Flower" . . .	20	20	20	20	19	..	..
"4"	22	21	22	22	..	..	..
"8"	21	21	22	22	20	..	..
"12"	19	20	20	20	19	..	..
"14"	20	20	20	19	19	..	..
				1924-25.			
"White Flower" . . .	..	..	..	..	..	..	..
"4"	21	20	21	21	..	..	..
"8"	20	20	19	19	..	..	..
"12"	19	19	19	19	17	18	..
"14"	18	19	19	19	19	18	..

From these figures it is clear that the cotton borne later in the season on the plant is of inferior staple. This was also found to be the case with *Broach deshi* cotton. It is curious to find that the second and third week of flowering often, though not always, gives a lint of longer staple than that resulting from the first flowers formed.

Another point of some interest is the fact that the white flowered type is quite up to the average in staple, though below the highest. There appears thus to be no sign of the correlation, which has been noticed by Burt[1] with cotton from *Gossypium neglectum*, between white flower and short staple.

(*h*) Seed weight.

The weight of the seeds in any type of cotton is by no means constant. It is reduced when the plants, on which the seeds are borne, are unhealthy, and when the seeds are from four celled bolls. It varies with the previous treatment of the land, whether in point of cultivation or on manuring, and with the part of the season in which the seeds grow. But even taking all these causes of variation into account it seems clear that in *Wagad* cotton just as in the *goghari*, and *Broach deshi* varieties, there are strains with heavy seed and strains with light seed, and that this character is hereditary.

This is clear from a consideration of the following figures of the average weight per seed (taken in each case from over 2,000 seeds) in six successive years in five pure strains.

Weight per seed in mg.

Strain	1919-20[1]	1920-21[1]	1921-22	1922-23	1923-24	1924-25
	mg.	mg.	mg.	mg.	mg.	mg.
"White Flower" . .	..	56·2	68·0	66·8	68·8	77·1
"4"	64·2	59·4	72·2	70·0	73·1	76·2
"8"	72·6	70·4	72·2	72·2	74·5	83·3
"12"	..	54·6	67·6	64·6	67·2	78·3
"14"	..	60·3	64·6	65·0	66·6	79·9

[1] The crop in the years 1919-20 and 1920-21 was grown at Broach rather out of its usual range.

The first observations on these figures is that the weight per seed is high throughout. In a year of great luxuriance, when grown under its own home conditions at Viramgam, the weight reaches very high figures indeed for Asiatic cotton, running to between 75 and 80 mg. per seed. When this is compared with the average for *Broach deshi* types (Studies in Gujarat Cottons, Part II, p. 216), which runs between 60 to 70 mg. for the heavier seeded type, and with the average for *goghari* types (Studies in Gujarat Cotton, Part I, p. 118), which gives about 62 mg.

[1] B. C. Burt. The Bundelkhand Cotton Experiments. *Agri. Res. Inst., Pusa, Bull.* No. 123.

for the heavier seeded strains, the real heaviness of these seeds will be evident. At the same time when grown outside its usual area (as in 1919-20 and 1920-21) the seed weight seems to be somewhat lower.

But the relationship between the seed weight of the different strains remains almost similar throughout, the only serious exception being the strain No. "4" in 1920-21, when grown outside its usual range. It is abundantly clear, in fact, that in spite of the seasonal and other causes of variation the production of light or heavy seeds is a matter of inheritance.

The weight of seeds produced at different parts of the season varies especially at the end of the season, when the seed is usually light. The figures given originated from flowers which opened in different parts of the season.

Seed weight.

Week of flowering.

Strain	(1)	(2)	(3)	(4)	(5)	(6)
	mg.	mg.	mg.	mg.	mg.	mg.
			1922-23			
"White Flower" . .	66	67	62	63	65	..
"4"	70	70	66	68	67	..
"8"	73	71	71	69	70	..
"12"	73	66	65	63	55	56
"14"	70	70	66	68	67	..
			1923-24			
"White Flower" . .	68	68	71	70	69	65
"4"	73	68	75	71	71	..
"8"	78	73	74	68	70	..
"12"	64	65	65	56	64	..
"14"	68	65	62	68	65	..
			1924-25			
"4"	87	81	77	52	..	..
"8"	79	85	73	63	..	..
"12"	79	76	74	73	73	57
"14"	79	80	75	71	65	61

There seems a slight, not very certain, progressive decrease in the seed weight upto the fifth week, though in certain cases (No. " 12 " in 1922-23 and No. " 4 " in 1924-25) there is a big fall in the fifth week. Seeds produced from flower in the sixth week of flowering are always light.

It will be noticed that the heavy seeded strains are also the big bolled types. This is in agreement with what has been found in the *Broach deshi* variety.

(*i*) Lint index and ginning percentage.

As has been already noted, the proportion of lint to seed in *Wagad* cotton stands fairly high, and the ginning percentage of the seed cotton as tested by market methods in the market at Viramgam is usually expected to be at least between 33 and 34 per cent. But there are many strains which give much higher than t s, and most of the selected types on which the present description is based do actually yield very much more cotton. Details cannot be given at this stage, but on the average of three years when grown at Viramgam the ginning outturn varies from 34·9 per cent. with " White Flower " to 42·8 per cent. with strain No. 8, while the best local mixed type of cotton (from Mandal village) gave 37 to 38 per cent. The highest of these figures exceed the ginning percentage obtained from the bulk even of *goghari* cotton, and are far in excess of the usual mixed types of *Broach deshi* grown in Surat or Broach.

The ginning percentage is, however, a complex conception, and in studying the variety, it is better to consider the lint index, or in other words, the weight of lint per 100 seeds.

The variation of the lint index in different parts of the season with pure strains of *Wagad* cotton is shown by the following data from the bolls produced from flowers opening in successive weeks throughout the season.

Lint index.

Week of flowering.

Strain	(1)	(2)	(3)	(4)	(5)	(6)
	grm.	grm.	grm.	grm.	grm.	grm.
			1922-23.			
" White Flower " . .	3·7	4·1	4·0	3·9	4·3	..
" 4 "	4·4	4·5	4·8	4·9	4·9	..
" 8 "	5·4	5·6	6·3	5·9	6·3	5·7
" 12 "	5·5	5·0	5·2	5·4	4·8	4·4
" 14 "	4·8	5·1	5·3	5·1	5·1	5·1

Lint index.

Week of flowering.

Strain.	(1)	(2)	(3)	(4)	(5)	(6)
	grm.	grm.	grm.	grm.	grm.	grm.
			1923-24.			
"White Flower" . .	3·0	3·0	3·1	3·6	3·2	..
"4"	4·2	4·1	4·2	4·3	..	..
"8"	5·1	5·1	5·3	4·9	4·9	..
"12"	4·2	4·4	4·5	4·5	4·4	4·5
"14"	4·2	4·6	3·9	4·4	3·9	..
			1924-25.			
"4"	5·2	5·4	5·4	3·9	..	..
"8"	4·8	6·0	4·9	3·8	..	..
"12"	4·9	5·1	4·9	4·7	4·2	3·5
"14"	4·7	5·0	4·5	4·3	3·9	4·3

It will be seen that as was found to be the case with the seed weight, the weight of lint per seed tends to decrease in the later developed bolls on the plant. This is not very obvious in the records of 1922-23, but is very marked in the other two years, included in the above figures. The first formed bolls usually also give seed cotton with a rather lower lint index than those formed in succeeding weeks, but this is not quite always the case.

The average lint index in these strains for six successive seasons was as under :—

Lint index in different seasons.

Strain	1919-20	1920-21	1921-22	1922-23	1923-24	1924-25
	grm.	grm.	grm.	grm..	grm.	grm.
"White Flower" . .	..	3·2	3·1	4·0	3·4	3·5
"4".	3·5	3·4	4·2	4·8	4·5	4·6
"8".	5·0	4·8	4·3	5·7	5·3	5·4
"12"	..	3·6	3·7	5·4	4·4	4 9
"14"	..	4·4	3·7	5·2	4·4	4·9

It will be seen that the types of cotton with low lint index retain this position throughout, and that similarly those with high lint index are also consistent in this respect. Hence this factor as a whole, in spite of its complex character, may be considered as hereditary. Where the differences are small, this hereditary feature may be partly masked by other factors, but in the extreme cases it is very clear.

IV. THE CORRELATION OF CERTAIN CHARACTERS IN *WAGAD* COTTON.

We have discussed in some detail the variability of some of the more important characters in pure strains of *Wagad* cotton. An enquiry may now be made as to whether the development of some of these characters is correlated with that of others in existing strains. The matter is important in the breeding of useful cottons, as such correlations may enable us to judge of the likelihood of certain combinations of qualities being obtainable. While too much stress should not be laid upon them, yet the suggestions which they give cannot be ignored.

In the present case only two such correlations have been studied, namely, that between seed weight and weight of lint per seed, and between seed weight and length of lint upon the seed. It may be stated at once that the correlation in the first case proves to be very high, while in the second case there appears to be little or no correlation whatever.

(*a*) *Correlation between seed weight and weight of lint per seed.* It is well known that this correlation does not exist universally among all types of cotton, and that even where it exists it varies very much in degree. There are numerous species and varieties of cotton where the seeds are large and the amount of lint small and *vice versâ*. But within a strain such a correlation may occur, and if so, it will be a very important point in judging the varieties in the produce in different periods of a season or of several seasons.

In pure *Broach deshi* types of cotton as isolated, the author has previously shown that there was a distinct positive correlation between the seed weight and weight of lint per seed, that is to say, as the seed weight increases so the weight of lint also increases though to a less extent. A similar relationship exists among the strains of *Wagad* cotton as is shown by the tables given in detail in the appendix, based in each case on the whole produce of one hundred plants in 1924-25.

From these figures the following relationships will be seen to exist :—

—	Strain No.			
	"4"	"8"	"12"	"14"
Mean seed weight	76·2 mg.	83·3 mg.	78·3 mg.	79·9 mg.
Mean lint weight per seed	45·9 mg.	54·6 mg.	49·3 mg.	48·9 mg.
Correlation coefficient	+0·644	+0·630	+0·783	+0·895
Probable error of correlation coefficient	±0·040	±0·040	±0·020	±0·013

The correlation would seem to be higher than was found to be the case in *Broach deshi* strain, but appears to be significant. The characters compared (seed weight and lint weight) per seed are not equally variable, the weight of lint in all cases varying considerably more than the seed weight. The variability of the two characters is shown in the following table :—

Coefficient of variability.

Strain	Seed weight	Lint weight
"4"	$9{\cdot}87 \pm 0{\cdot}47$	$12{\cdot}94 \pm 0{\cdot}62$
"8"	$7{\cdot}91 \pm 0{\cdot}37$	$10{\cdot}63 \pm 0{\cdot}51$
"12"	$10{\cdot}51 \pm 0{\cdot}50$	$14{\cdot}31 \pm 0{\cdot}68$
"14"	$9{\cdot}84 \pm 0{\cdot}47$	$10{\cdot}39 \pm 0{\cdot}50$

(*b*) *Correlation between seed weight and length of lint.* In the author's study of *Broach deshi* types of Gujarat cotton, it was found that there was apparently a relationship between the seed weight and the *length* of the lint in the heavy seeded strains, and that, at any rate, among the bolls of a single plant, the heavier the seed the longer was the lint likely to be. If such a relationship exists generally, it would be most important. But it was found not to be visible in the lighter seeded strains of *Broach deshi* cotton, and now it does not appear to exist, at any rate, between cotton from different plants of the strain, among the pure types of *Wagad* cotton.

The figures from which this statement is made are shown in the following table where the length of the staple is taken from the middle of the seed.

Strain	Mean seed weight	Mean length of staple	Correlation coefficient
	mg.	mg.	
"4"	76·2	20·6	$+0{\cdot}24 \quad \pm 0{\cdot}06$
"8"	83·3	19·9	$-0{\cdot}06 \quad \pm 0{\cdot}0$
"12"	78·3	19·2	$+0{\cdot}20 \quad \pm 0{\cdot}06$
"14"	79·9	19·2	$+0{\cdot}18 \quad \pm 0{\cdot}06$

There is evidently no relationship whatever in these strains between the lint length and the seed weight of different plants.

V. DESCRIPTION OF CERTAIN PURE LINE STRAINS OF *WAGAD* COTTON.

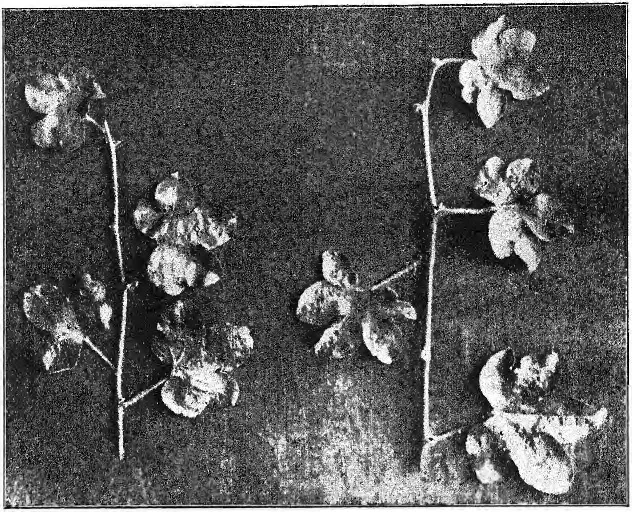
The characters which differentiate the *Wagad* variety of *Gossypium herbaceum* from the *goghari* and from the *Broach deshi* varieties of the same species have been described in the author's previous memoir, and also in the earlier part (p. 62) of the present paper. But in the types which have the characteristics of *Wagad* cotton there are many strains which differ from one another by characters which are of direct or indirect economic importance, and which breed true. These strains are, however, not merely mixed. They have crossed with one another to a very great extent, and few if any of a pure character now exist in cultivation. Any attempt to make a permanent improvement in the character of the cotton grown or even to fix a type which shall approach near to the ideal for the area where *Wagad* is at present grown must be commenced by the isolation of such pure strains, breeding true, which can be used as the basis for establishing types or of making crosses with other varieties of cotton.

It is now proposed to describe six such pure strains which have been isolated, in order to indicate the range of variation which exists in *Wagad* cotton, and also the fluctuation within the strain itself. The strains were isolated from material obtained in the Ahmedabad area (Sanand, Viramgam, etc.) in 1917-18. The strains described have been in pure line culture since 1919-20, 1920-21, or 1921-22. The isolations were made at Broach outside the area where the variety is usually grown, but since 1921-22 they have been grown in its own districts. It must be recognised that the types described are from one area only, and hence the variation more particularly in drought resistance and in time of ripening, is much smaller than would be found if samples were collected over the whole range of the variety, including Kutch. Collection of types from these outlying areas is still to do, and it is hoped to undertake it in the next year.

Strain "4." The first of these strains to be described has been termed "4" and is derived from a selection originally made in 1917-18 on the basis of giving a large round boll, with a markedly pointed tip. The progeny of the original seed varied much in 1918-19. From 1919-20 plants secured from self fertilised parent have been uniform, and have been maintained from protected flowers. It has bred true since then with the following characters.

1. The number of primary monopodia in this strain has been about the average for the variety. As in other cases, the number in 1921-22, when the plants were grown on a more sandy soil at Sanand was high. The results in the succeeding years at Viramgam represent more nearly the habit of the plant in its own region. The actual average number of primary monopodia recorded was as follows :—

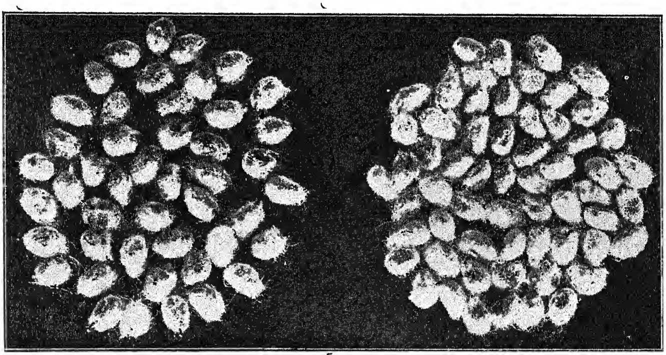
1921-22	(Sanand)	— 8·1
1922-23	(Viramgam)	—4·3
1923-24	,,	—4·8
1924-25	,,	—3·2



(1)

Left. *Wagad* strain "4"—leaves with middle lobes broad.

Right. *Wagad* strain "14"—leaves with middle lobes tapering and deeply sected.



(2)

Left. Seeds of *Wagad* strain "8" with characteristic distinct thorn at tip as in the *Wagad* variety.

Right. Seeds of *Broach-deshi* with almost invisible thorn at tip.

The leaves have broader lobes than any other strain. Plate III (1).

(2) The most frequent node from which the first primary fruiting branch arises has been the 13th (counting from the base in every year except 1923-24) when it was the 8th as that was a very early season.

(3) The average measurements of the bolls in centimeters were as follows in four separate years. The figures relate to three celled bolls only :—

—	1921-22	1922-23	1923-24	1924-25
	cm.	cm.	cm.	cm.
Greatest diameter	2·7	2·6	2·6	2·7
Length from gland to tip	3·1	2·8	2·8	2·8
Width of boll at 7 mm. from tip . .	1·1	1·2	1·1	1·1

These figures are, as stated, for three celled bolls. There is, however, in this strain a larger proportion of four celled bolls than in any other.

The length of bolls in this case is greater than in any other of the round bolled types, indicating the long tip which it possesses. The bolls open on ripening a little more than is usual with *Wagad* cotton, and thus the cotton is more exposed and is liable to be more dirty than with other types. The opening of the bolls is peculiar in that the tip of the boll is distinctly visible (Plate 1, fig. 2). This charater is believed by the merchants to be indicative of a high staple cotton. And certainly (see below) the staple in this case is higher than in any other of the strains.

(4) The average weight of each seed (average of nearly 2,000 seeds in each case) is as follows :—

1919-20	64·2 mg. (Broach)
1920-21	59·4 ,, (Broach)
1921-22	72·2 ,, (Sanand)
1922-23	70·0 ,, (Viramgam)
1923-24	73·1 ,, (Viramgam)
1924-25	76·2 ,, (Viramgam)

The seeds are the heaviest among the types isolated, except in the case of No. 8.

(5) The average weight of lint per 100 seeds (lint index) in six successive years is as follows :—

1919-20	3·5 grm. (Broach)
1920-21	3·4 ,, (Broach)
1921-22	4·2 ,, (Sanand)
1922-23	4·8 ,, (Viramgam)
1923-24	4·4 ,, (Viramgam)
1924-25	4·6 ,, (Viramgam)

Where the seed weight is varying the lint index forms a better means of comparison between the proportion of lint to seed in different strains and in different seasons than the ginning percentage. This last figure (ginning percentage) is as follows in the years quoted :—

	Per cent.
1919-20	35·0 (Broach)
1920-21	36·5 (Broach)
1921-22	37·0 (Sanand)
1922-23	40·9 (Viramgam)
1923-24	37·8 (Viramgam)
1924-25	37·5 (Viramgam)

The ginning percentage is lower than in any of the other strains selected for multiplication, but it is nevertheless higher than that of the ordinary mixed cotton grown round Viramgam.

(6) The length of staple is the highest among the selections made, and represents the best that has been obtained up to the present from *Wagad* cotton. The following are the average measurements of the lint on different parts of the seed.

——	1920-21	1921-22	1922-23	1923-24	1924-25
	mm.	mm.	mm.	mm.	mm.
Lint on tip of seed	21·1	18·6	17·9	17·3	..
Lint on middle of seed	23·8	22·2	21·1	20·8	20·7
Lint on base of seed	23·2	19·8	20·3	19·9	..

The variation from the mean taking the first four years together (*a*) at the tip was 9·4 per cent. below, (*b*) at the middle 6·7 per cent. above and (*c*) at the base was 1·5 per cent. above the mean.

The lint on the middle of the seed varied as follows. The variation was determined in all years except 1922-23 and 1923-24 from 100 seeds, and in the two years named from 400 seeds :—

——	1920-21	1921-22	1922-23	1923-24	1924-25
Number of measurements made	100	100	400	400	100
	per cent.	per cent.	per cent.	per cent.	per cent.
Staple of below 1·7 cm.	..	..	1·7	..	..
Staple of 1·7 to 1·9 ,,	..	..	6·8	2·6	1·2
Staple of 1·9 to 2·1 ,,	1·0	17·0	23·3	23·7	35·0
Staple of 2·1 to 2·3 ,,	22·0	55·0	50·1	69·5	62·6
Staple of 2·3 to 2·5 ,,	39·0	25·0	15·0	4·2	1·2
Staple of 2·5 to 2·7 ,,	37·0	2·0	2·0	..	..
Staple over 2·7 cm.	1·0	..	..	..	..

The variation is illustrated in figure 3 below :—

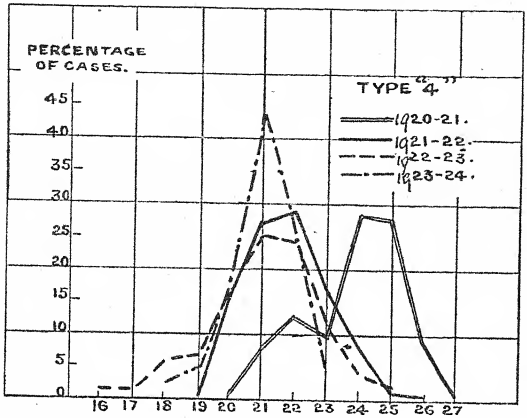


FIG. 3. Length of staple in mm.

(7) The lint from this strain was examined by Messrs. R. D. Tata & Co. with the following results :—

Value of lint per candy of 784 pounds.

Year	Good local *Wagad* cotton from Mandal	Type No. "4"
	Rs.	Rs.
1921-22	510	520
1922-23	520	565
1923-24	575—580	610
1924-25	450	450

Thus in every case it is at least equal in value to the best type of local *Wagad* cotton and generally is distinctly higher, while it has a higher ginning outturn.

Strain "*8*." In the same year as the strain previously described, that now under consideration was selected at Sanand. It was chosen on account of its large spherical boll. It has been found to be pure from 1919-20, and has been maintained from that year from selfed flowers.

(1) The plants of this strain are rather short in habit of growth, and also have the least number of primary monopodia of any of the selections. The actual average number recorded has been as follows :—

Average number of monopodia.

1921-22	6·6 (Sanand)
1922-23	3·2 (Viramgam)
1923-24	3·1 (Viramgam)
1924-25	2·5 (Viramgam)

(2) The most frequent node from which the first primary fruiting branch arises has been the 10th to the 12th, except in 1923-24 when all types bore fruiting branches at a lower level than usual. In that year the node was most frequently the 6th or 7th.

In this strain the node is lower than in any other selection except in the " White Flower " to be afterwards described.

The importance of these primary fruiting branches (sympodia) is greatest with this strain, as it bears a larger proportion of its crop on these branches than in any other case.

(3) The average measurements of the bolls in centimeters was as follows in four separate years. The figures relate to the three celled bolls only :—

—	1921-22	1922-23	1923-24	1924-25
	cm.	cm.	cm.	cm.
Greatest diameter	2·7	2·6	2·5	2·7
Length from gland to tip	2·9	2·7	2·6	2·8
Width of boll at 7 mm. from tip . .	1·1	1·2	1·1	1·2

The bolls are hence large, like those of strain " 4," though more round. They have also a well marked tip, but it is not developed to such an extent as in the strain previously described. They open very similarly to the latter.

(4) The average weight per seed is as follows :—

	mg.
1919-20	72·6 (Broach)
1920-21	70·4 (Broach)
1921-22	72·2 (Sanand)
1922-23	72·2 (Viramgam)
1923-24	74·5 (Viramgam)
1924-25	83·3 (Viramgam)

The seeds are the heaviest in all the selected strains and have been less affected by change in locality than any of the others.

The average weight of lint per 100 seeds (lint index) in six successive years is shown below :—

Lint index.

	grm.
1919-20	5·0 (Broach)
1920-21	4·8 (Broach)
1921-22	4·3 (Sanand)
1922-23	5·7 (Viramgam)
1923-24	5·3 (Viramgam)
1924-25	5·5 (Viramgam)

The ginning percentage is as follows in the years quoted :—

Ginning percentage.

	Per cent.
1919-20	40·7 (Broach)
1920-21	40·7 (Broach)
1921-22	37·2 (Sanand)
1922-23	44·1 (Viramgam)
1923-24	41·4 (Viramgam)
1924-25	39·6 (Viramgam)

This figure is hence very high, going over 40 per cent. ginning percentage on the average of six years.

(6) The lint gave the following average measurements in different parts of the seeds in five successive years.

Length of staple.

——	1920-21	1921-22	1922-23	1923-24	1924-25
	cm.	cm.	cm.	cm.	cm.
Lint on tip of seed	1·9	1·6	1·6	1·6	..
Lint on middle of seed	2·2	2·1	2·0	2·0	2·0
Lint on base of seed	2·1	1·8	1·9	1·9	..

The variations from the mean, taking the first four years together (*a*) at the tip was 11·7 per cent. below the mean, (*b*) at the middle was 8·1 per cent. above the mean and (*c*) at the base was 1·6 per cent. above the mean.

The lint on the middle of the seed varied as follows, as determined from 100 measurements, in each of five successive years.

——	1920-21	1921-22	1922-23	1923-24	1924-25
Staple of 1·5 to 1·69 cm.	..	..	2·3	..	..
,, 1·7 to 1·89 ,,	1·0	..	17·1	8·6	1·6
,, 1·9 to 2·09 ,,	9·0	55·5	41·0	59·4	81·5
,, 2·1 to 2·29 ,,	37·0	43·0	37·7	31·7	16·8
,, 2·3 to 2·49 ,,	43·0	1·5	1·8	0·2	..
,, 2·5 or over ,,	10·0	..	..	..	..

The variation is illustrated in Fig. 4 below :—

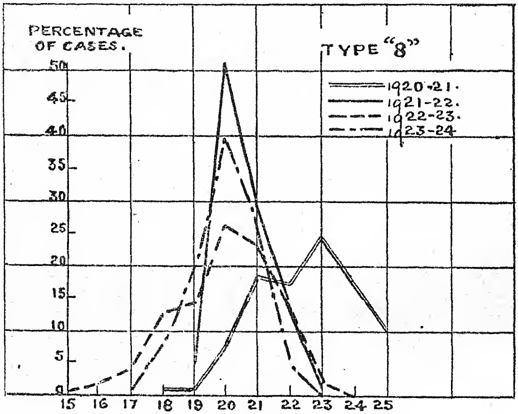


FIG. 4. Length of staple in mm.

(7) The lint from this strain was examined by Messrs. R. D. Tata & Co. with the following results :—

Value of lint per candy of 784 pounds.

Year	Good local *Wagad* cotton from Mandal	Type No. "8."
	Rs.	Rs.
1921-22	510	475
1922-23	520	550
1923-24	575—580	590
1924-25	450	435

In some years this has proved the highest yielding strain among the selections, and for this reason it has been maintained.

Strain " 12." This strain was selected in 1917-18, as a type with small spherical bolls. It was found to be pure in 1920-21, and has been propagated since that time from protected flowers. (1) The plants of this type are tall in habit of growth, but the plants (unlike strain " 14 " to be afterwards described) are not spreading, or, in other words, the branches are not long. The number of monopodia is high, as the following figures show :—

Average number of monopodia.

1921-22	10·1 (Sanand)
1922-23	5·2 (Viramgam)
1923-24	4·8 (Viramgam)
1924-25	5·0 (Viramgam)

(2) The most frequent node from which the first primary fruiting branch arises is high in the plant. In all the recorded years (1921-22 to 1924-25) it has always been between the 13th and the 15th node, except in 1923-24 (a very early season) when it was the 8th.

The proportion of the crop borne on such primary fruiting branches is the lowest in all the selected strains ; the primary monopodia carry the largest percentage of bolls. The number of flower buds is lower in this type in proportion to the vegetative growth (in nodes) than in others.

(3) The average measurements of the bolls in centimeters was as follows in four separate years. The figures relate to three celled bolls only :—

Measurement of Bolls.

——	1921-22	1922-23	1923-24	1924-25
	cm.	cm.	cm.	cm.
Greatest diameter	2·6	2·5	2·4	2·6
Length from gland to tip	2·7	2·5	2·5	2·7
Width of boll at 7 mm. from tip	1·2	1·2	1·2	1·2

The bolls are, therefore, distinctly smaller than those of strains " 4 " and " 8." They open very slightly when ripe, much less in fact than strains " 4 " and " 8," and thus the cotton is usually marketed very clean.

The average weight per seed is shown in the following figures :—

Weight per seed.

	mg.
1920-21	54·6 (Broach)
1921-22	67·6 (Sanand)
1922-23	64·6 (Viramgam)
1923-24	67·2 (Viramgam)
1924-25	78·3 (Viramgam)

The seeds are thus consistently light, as compared with other strains

(5) The weight of lint per 100 seeds (lint index) has been as follows :—

Lint index.

	grm.
1920-21	3·6 (Broach)
1921-22	3·7 (Sanand)
1922-23	5·4 (Viramgam)
1923-24	4·4 (Viramgam)
1924-25	4·9 (Viramgam)

The ginning percentage is as follows in the years quoted :—

Ginning percentage.

	Per cent.
1920-21	39·5 (Broach)
1921-22	35·6 (Sanand)
1922-23	45·4 (Viramgam)
1923-24	39·9 (Viramgam)
1924-25	38·7 (Viramgam)

This figure is hence very high and is only exceeded by that for strain "8."

(6) The lint gave the following average measurements in different parts of the seeds in five successive years :—

Length of staple.

—	1920-21	1921-22	1922-23	1923-24	1924-25
	cm.	cm.	cm.	cm.	cm.
Lint on tip of seed	1·7	1·7	1·6	1·6	..
Lint on middle of seed	2·1	2·1	2·0	2·0	1·9
Lint on base of seed	2·0	1·9	1·9	1·8	..

The variation from the mean taking the first four years together, (*a*) at the t'p was 12 per cent. below the mean, (*b*) at the middle was 8 per cent. above the mean and (*c*) at the base was 2·1 per cent above the mean.

The length of the lint on the middle of the seed varied as follows, as determined from 100 measurements in each of five successive years :—

—	1920-21	1921-22	1922-23	1923-24	1924-25
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Staple of 1·5 to 1·69 cm.	..	..	2·1	..	..
,, 1·7 to 1·89 ,,	6·0	0·5	20·8	13·0	3·3
,, 1·9 to 2·09 ,,	16·0	48·0	50·7	70·1	96·0
,, 2·1 to 2·29 ,,	58·0	48·5	25·3	16·8	0·7
,, 2·3 to 2·49 ,,	20·0	3·0	0·9	..	..
,, 2·5 and over	..	..	..	..	..

The variation is illustrated in figure 5 below :—

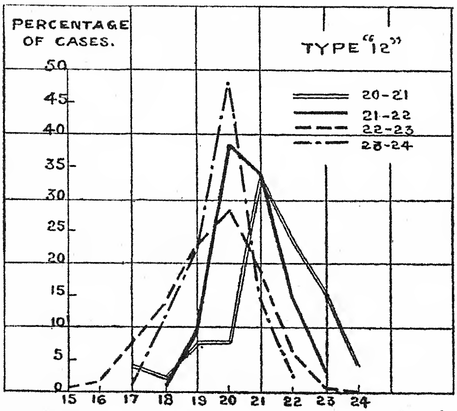


FIG. 5. Length of staple in mm.

(7) The lint from the strain was examined by Messrs. R. D. Tata & Co., with the following results :—

Value of lint per candy of 784 pounds.

Year	Good local *Wagad* cotton	Type No. " 12 "
	Rs.	Rs.
1921-22	510	490
1922-23	520	500
1923-24	575 to 580	590
1924-25	450	450

This type has consistently given the highest yield of any *Wagad* cotton and is thus of great economic value.

Strain " 14." This strain was another selection of 1917-18, as a type with small spherical bolls. It has been pure since 1921-22, and has been propagated since that time from protected flowers.

(1) The plants of this type are tall in habit of growth, with spreading primary monopodia and axillary branches, giving almost the appearance of a *Broach deshi* type (plate II). The leaves are more hairy than other types, and the leaf lobes are longer and more tapering than in strain " 4." The number of monopodia is high, the average number being as follows :—

Average number of monopodia.

1921-22	7·0 (Sanand)
1922-23	4·5 (Viramgam)
1923-24	5·0 (Viramgam)
1924-25	5·0 (Viramgam)

(2) The first primary sympodium arises at a higher node than in any other selection. The actual node most frequently found was the 14th or 15th in 1921 to 1924, except in 1923, when it started much lower, at the 8th or 9th.

(3) The average measurements of the bolls in centimeters has been as follows in four separate years. The figures are for three celled bolls only.

Measurements of bolls.

	1921-22	1922-23	1923-24	1924-25
	cm.	cm.	cm.	cm.
Greatest diameter	2·6	2·6	2·4	2·6
Length from gland to tip	2·7	2·5	2·4	2·6
Width of boll at 7 mm. from tip	1·2	1·2	1·2	1·2

The bolls are very similar in size and shape, therefore, to those found in strain "12" and they open very slightly on ripening and thus produce a very clean cotton.

(4) The average weight per seed is shown in the accompanying figures :—

Weight per seed.

	mg.
1921-22	64·5 (Sanand)
1922-23	65·0 (Viramgam)
1923-24	66·4 (Viramgam)
1924-25	79·9 (Viramgam)

The seeds correspond in weight closely with strain "12" and are much lighter than in strains "4" and "8."

(5) The weight of lint for 100 seeds (lint index) has been as follows :—

Lint index.

	grm.
1921-22	3·7 (Sanand)
1922-23	5·2 (Viramgam)
1923-24	4·4 (Viramgam)
1924-25	4·9 (Viramgam)

The ginning percentage was as follows in the years quoted :—

Ginning percentage.

1921-22	36·4 (Sanand)
1922-23	44·7 (Viramgam)
1923-24	40·0 (Viramgam)
1924-25	37·9 (Viramgam)

The ginning outturn is thus almost as high as in strains "8" and "12."

(6) The lint gave the following average measurements in different parts of the seeds in four successive years.

Length of staple.

—	1921-22	1922-23	1923-24	1924-25
	cm.	cm.	cm.	cm.
Lint on tip of seed	1·8	1·5	1·6	..
Lint on middle of seed	2·1	1·8	2·0	1·9
Lint on base of seed	1·9	1·8	1·9	..

The variation from the mean, taking the first three years together, (*a*) at the tip was 11·1 per cent. below the mean, (*b*) at the middle was 7·5 per cent. above the mean and (*c*) at the base was 1·9 per cent. above the mean.

The length of the lint from the middle of the seed varied as follows :—

—	1921-22	1922-23	1923-24	1924-25
	Per cent.	Per cent.	Per cent.	Per cent.
Staple of 1·5 to 1·69cm.	0·5	13·8	..	..
,, 1·7 to 1·89 ,, ...	0·5	42·2	10·1	3·2
,, 1·9 to 2·09 ,, ...	28·0	36·5	56·3	95·0
,, 2·1 to 2·29 ,, ...	62·0	6·5	31·2	1·8
,, 2·3 to 2·49 ,, ...	9·5	0·7	12·5	0·2

The variation is illustrated in Figure 6 below.

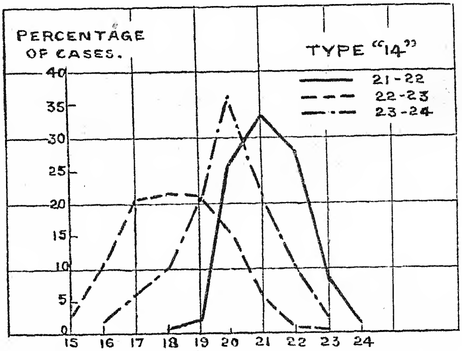


FIG. 6. Length of staple in mm.

The lint is, it will be seen, somewhat inferior at least to that of strains " 4 " and " 8."

(7) The lint from this strain was examined by Messrs. R. D. Tata and Co. with the following results.

Value of lint per candy of 784 pounds.

Year	Good local *Wagad* cotton from Mandal	Type No. "14"
	Rs.	Rs.
1921-22	510	485
1922-23	520	540
1923-24	575—580	590
1924-25	450	450

Strain "*White Flower.*" This strain of *Wagad* cotton about to be described has been retained in our collection on account of its peculiarity in possessing a white flower. It is not likely to have any direct economic value, but in as much as *Gossypium herbaceum* has been always described as having yellow flowers exclusively, the occurrence of such a typical strain of *Wagad* cotton with white flowers deserves to be recorded. It is derived from one of four plants originally selected in 1917-18, having white and small petals, white and big petals, and sulphur white big petals. Success was only achieved in purifying one of the lots with white and small petals and this has been maintained pure since 1920.

(1) The plants of this strain have a small number of primary monopodia. The average number was as follows :—

Average number of monopodia.

1921-22	7·3 (Sanand)
1922-23	3·5 (Viramgam)
1923-24	3·9 (Viramgam)

(2) The first primary sympodium arises most frequently from about the 11th node, though in 1923-24 with a very early season, it arose from the 7th node, a change which was similar to that found in other strains.

Though this strain has a small number of primary monopodia, the primary fruiting branches are not as strong as would be expected, or as they are in strain "8." The formation of flower buds in proportion to the vegetative growth is the highest of any other strain, but there is a higher loss by shedding of both flower buds (in dry seasons specially) and flowers (in all seasons). It is suggested that this large loss by shedding may be due to the clustering habit of growth of flower buds at the end of the season. The percentage success of flower buds in the early part of the season is high.

(3) The average measurements of the bolls in centimeters was as follows in four separate years. The figures relate to three celled bolls only.

Measurements of bolls.

——	1921-22	1922-23	1923-24	1924-25.
	cm.	cm.	cm.	cm.
Greatest diameter	2·6	2·5	2·6	2·7
Length of gland to tip	2·7	2·6	2·6	2·8
Width of boll at 7 mm. from tip	1·1	1·2	1·1	1·1

4. The average weight per seed is shown in the accompanying figures.

Weight per seed.

	mg.
1919-20	57·6 (Broach)
1920-21	56·2 (Broach)
1921-22	68·0 (Sanand)
1922-23	66·8 (Viramgam)
1923-24	68·8 (Viramgam)
1924-25	77·0 (Viramgam)

(5) The weight of lint per 100 seeds (lint index) has been as follows :—

Lint index.

1919-20	2·8 (Broach)
1920-21	3·2 (Broach)
1921-22	3·0 (Sanand)
1922-23	4·0 (Viramgam)
1923-24	3·4 (Viramgam)
1924-25	3·5 (Viramgam)

The ginning percentage was as follows in the years quoted.

Ginning percentage.

	Per cent.
1919-20	32·5 (Broach)
1920-21	36·0 (Broach)
1921-22	31·1 (Sanand)
1922-23	37·4 (Viramgam)
1923-24	33·2 (Viramgam)
1924-25	31·2 (Viramgam)

This is obviously an undesirable type on account of its low ginning percentage and the white flower character is not correlated with high ginning percentage.

6. The lint gave the following average measurements in different parts of the seeds in four successive years.

——	1921-22	1922-23	1923-24	1924-25
	cm.	cm.	cm.	cm.
Lint on tip of seed	1·8	1·6	1·6	..
Lint on middle of seed	2·1	2·0	2·0	2·0
Lint on base of seed	1·9	1·9	1·8	..

The variation from the mean, taking the first three years together, (*a*) at the tip was 10·3 per cent. below the mean, (*b*) at the middle was 7·9 per cent. above the mean and (*c*) at the base was 0·9 per cent. above the mean.

The length of the lint from the middle of the seed varied in the manner shown in the attached table, as determined from 100 measurements in each of four successive years.

——	1921-22	1922-23	1923-24	1924-25
	Per cent.	Per cent.	Per cent.	Per cent.
Staple of 1·5 to 1·69 cm.	..	0·3	..	..
,, 1·7 to 1·89 ,,	..	19·6	14·7	4·6
,, 1·9 to 2·09 ,,	47·5	47·3	80·0	84·8
,, 2·1 to 2·29 ,,	50·0	29·8	5·2	10·6
,, 2·3 to 2·49 ,,	2·5	2·5	..	..

The variation is illustrated in Figure 7 below.

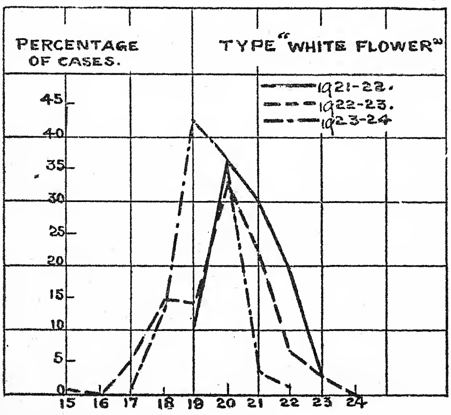


Fig. 7. Length of staple in mm.

(7) The lint was examined by Messrs. R. D. Tata & Co., with the following results.

Value of lint per candy of 784 pounds.

Year	Good local *Wagad* cotton from Mandal	Type "White Flower"
	Rs.	Rs.
1921-22	510	500
1922-23	525	540
1923-24	575 to 580	590

The feel of the cotton in this strain is noted as particularly nice.

This strain is maintained in the collections because of its peculiarity of bearing white flowers, and because of the clustered habit of the flower buds.

Strain "Long boll." This, the last strain to be described, is introduced rather to show the amount of variation which occurs among the general population of fields of *Wagad* cotton as grown in the Ahmedabad District. It is derived from a selection made in 1917-18, on the basis of its tapering long bolls. The progeny showed great variation in 1918-19, but from 1920-21 a constant type was secured, which has been under close detailed observation since 1922-23, as produced from protected flowers.

As this strain has not been found of any economic use, it has been tested on small plots, a few feet square planted by dibbling at intervals of three feet in each direction. Thus the habit of the plant will not be entirely comparable with that of plants drilled one foot apart in rows themselves two feet apart. But it represents one of the many types existing in the local *Wagad* cotton, which by themselves are of no economic value.

(1) The plants are almost as bushy as strain "8," and had an average of 4·2 primary monopodia in 1922-23, 3·7 in 1923-24, and 4·6 in 1924-25.

The most frequent node for the first fruiting primary branches was the 9th in 1922-23, the 6th in 1923-24, and the 12th in 1924-25.

(3) The average measurements of the bolls in centimeters in 1924-25 were as under.

Measurements of bolls.

	1924-25
	cm.
Greatest diameter	2·7
Length from gland to tip	3·1
Width of boll at 7 mm. from the tip	1·0

It will be seen that this is not nearly so spherical as the bolls previously described. It represents a shape of bolls which always occurs in limited quantity

in local *Wagad* cotton as now grown, characterized by greater length than the typical *Wagad* bolls.

(4) The average weight per seed is shown in the accompanying figures. All were grown at Viramgam.

Weight per seed.

	mg.
1922-23	66·8
1923-24	75·5
1924-25	76·5

The seeds are thus somewhat heavier than the average, but not markedly so.

(5) The weight of lint per 100 seeds (lint index) has been as follows :—

Lint index.

	grm.
1922-23	4·8
1923-24	4·4
1924-25	4·7

The ginning percentage in the three years quoted may also be given. All were grown at Viramgam.

Ginning percentage.

	Per cent.
1922-23	41·7
1923-24	36·7
1924-25	38·3

Thus, on the whole, ginning outturn is distinctly above that of the lower types like "White Flower;" it is distinctly below the best strains "8", "12" and "14."

(6) The lint gave the following average measurements in different parts of the seed in the three successive years :—

Length of staple.

—	1922-23	1923-24	1924-25
	cm.	cm.	cm.
Lint on tip of seed	1·7	1·7	..
Lint on middle of seed	2·0	2·1	2·0
Lint on base of seed	2·0	2·0	..

Further details are not available with regard to this typical example of the strains of mediocre performance which form some part of much of the *Wagad* cotton now under cultivation in Ahmedabad District.

Comparison of strains of Wagad cotton. From the description of five strains (that last described is excluded in the present comparison) which have been maintained as of some economic use either as such or as a basis for crossing, it will be seen that each has some special quality which gives it either interest or value. We may now summarize the commercial qualities of these types in respect to the yield per acre at Viramgam, the ginning percentage of the *Kapas*, the length of the staple of the lint, and the market value of the lint. In the case of yield, the results are based on the season 1922-23 or 1923-24, as the results of 1924-25 were vitiated by an accident. In other cases, the results are based on two or on three years' figures.

Strain	Yield of Kapas per acre	Yield of lint per acre	Ginning percentage	Value per candy	Value of lint per acre	Average length of staple. Middle of seed
	lb.	lb.	Per cent.	Rs	Rs.	cm.
"4"	603	240	39·8	587·5	179·8	2·09
"8"	627	268	42·8	570	194·8	2·00
"12"	639	269	42·2	545	187·0	1·95
"14"	598	252	42·2	565	181·6	1·92
"White Flower" Best local	476	166	34·9	565·5	119·6	1·98
Type from Mandal	628	237	37·8	548·5	165·8	1·96

VI. THE IDEAL TYPE OF *WAGAD* COTTON FOR UPPER GUJARAT.

The climate and soil conditions in the *Wagad* cotton area, as described in the early part of the present Memoir, are so different from those prevailing in Lower Gujarat, that the characteristics of the ideal plant which we are seeking will not be necessarily, by any means, the same as those, set out for that region. It is, therefore, necessary at least to indicate where the type of plant which we now want will differ from those previously described.

It may at once be stated that here as everywhere else, the best results can only be obtained where a pure line of strain of cotton is used. By this means a constancy is brought into the cotton marketed which is of immense value. This, however, does not now exist, and has never been even attempted, unlike what is found in some parts of Lower Gujarat. Further the staple and ginning percentage must

both be as high as possible, and also the yielding power of the plants must be high and not be very variable from year to year.

Apart from these demands which apply everywhere, the characters which our investigations seem to show as necessary for the best results are :—

1. The vegetative growth of the plant should be vigorous, and, so far as we know now, those types with the most vigorous growth will also be the best yielders. This statement applies equally to large monopodial growth and to a large development of axillary vegetative branches.

This point is illustrated by figures for three years in which for strains "White Flower," "8," and "12," we can compare the vegetative growth (limbs and axillaries) *in nodes* and the number of flower buds—taken from twenty plants in each case.

Ratio of number of flower buds to nodes of vegetative growth.

Strain	1922-23	1923-24	1924-25
"White flower"	0·93	1·59	..
"8"	0·91	1·12	0·93
"12"	0·64	1·00	0·64

We have already seen that the strain "12" is the heaviest yielder, and it is also (by this test) the most strong growing on the vegetative side.

2. The number of fruiting branches both primary and secondary should be high, though a development of these branches in length is not desirable.

3. An early flowering type is more desirable. In this respect, the kind of plant to be aimed at is quite different from what has been found to be the case with *Broach Deshi* strains in Lower Gujarat. *There*, an early flowering type was usually a low yielder because of the very great loss of the early buds and flowers by shedding. *Here*, among the *Wagad* strains the early flowers are the most successful, and hence an early flowering type is to be desired.

4. The bolls should be large, and *should open as little as possible*. The size of the bolls is an even more important matter with *Wagad* cottons than among those from which the seed cotton is removed in the field. In the *Wagad* variety the whole crop is picked in one instalment late in the season. The ginning season is, therefore, very short as ginning must be completed before the monsoon, unless the bolls are to be left over till next year. In this time the bolls have to be broken open and the seed cotton extracted. As labour is scarce, big bolls are an advantage, for, people will not undertake the work with the smaller boll types.

Further, any type which opens considerably in the field is liable to give a dirtier cotton, and hence the less the opening the greater the advantage. Some of our smaller boll strains (Nos. "12" and "14") have the advantage in this respect, but at present the advantage is not sufficient to overcome the disadvantage of the smaller boll.

A large part of the advantage of the big bolls would be removed if the opening of the bolls and extraction of the cotton could be done by machinery. It is understood that such machinery has been developed and is used in Asiatic Turkey for the *Wagad* cotton grown there, and if its use could be introduced it would be of great advantage.

Acknowledgment.

We take the opportunity to express gratitude to Dr. H. H. Mann, who has guided the work during its progress and finally assisted us greatly in compiling the results now presented.

APPENDIX.

WAGAD COTTON.

Correlation frequencies between seed weight and weight of lint per seed in milligrams.

WAGAD "14" (98 PLANTS EXAMINED.)

LINT WEIGHT	SEED WEIGHT											
	54·1 58·0	58·1 62·0	62·1 66·0	66·1 70·0	70·1 74·0	74·1 78·0	18·1 82·0	82·1 86·0	86·1 90·0	90·1 94·0	94·1 98·0	F.
29·1 33·0	1											1
33·1 37·0	1				1							2
37·1 41·0		2				1						3
41·1 45·0			1	6	5	1	1	1				15
45·1 49·0					1	5	11	4	2	1		24
49·1 . . .						5	10	9	6			30
53·1 57·0						2	3	8	6	0	1	20
57·1 61·0								1			2	3
F.	2	2	1	6	7	14	25	23	14	1	3	98

WAGAD "12" (99 PLANTS EXAMINED).

	51·1 54·0	54·1 58·0	58·1 62·0	62·1 66·0	66·1 70·0	70·1 74·0	74·1 78·0	78·1 82·0	82·1 86·0	86·1 90·0	90·1 94·0	F.
24·8										1		1
20·1 33·0 . . .				1								1
33·1 37·0 . . .	1	1	1	1								4
37·1 41·0 . . .			2	1	1							4
41·1 45·0 . . .			1	1	4	3	3	1				13
45·1 49·0 . . .						5	6	10	2			23
49·1 53·0 . . .					1	1	4	7	7	2		22
53·1 57·0 . . .							1	6	9	6		22
57·1 61·0 . . .									2	1		3
61·1 65·0 . . .									2	2	1	5
65·1 69·0 . . .											1	1
F.	1	1	4	4	6	9	14	24	22	12	2	99

Correlation frequencies between seed weight and weight of lint per seed in milligrams.

WAGAD "8" (99 PLANTS EXAMINED).

LINT WEIGHT	SEED WEIGHT										
	58·1 62·0	62·1 66·0	66·1 70·0	70·1 74·0	74·1 78·0	78·1 82·0	82·1 86·0	86·1 90·0	90·1 94·0	94·1 98·0	102·1 106·0	F.
33·1 37·0 . . .	1											1
37·1 41·0 . . .			1									1
41·1 45·0 . . .		1		1		1						3
45·1 49·0 . . .				1	4	2						7
49·1 53·0 . . .					3	13	6	4	1			27
53·1 57·0 . . .				2		7	6	7	3			25
57·1 61·0 . . .					2	1	9	6	4	1		23
61·1 65·0 . . .						3	4	2	1			10
65·1 69·0 . . .								1			1	2
F	1	1	1	4	9	27	25	20	9	1	1	99

WAGAD "4."

	39·0	58·1 62·0	62·1 66·0	66·1 70·0	70·1 74·0	74·1 78·0	78·1 82·0	82·1 86·0	86·1 90·0	90·1 94·1	F.
24·8	1										1
29·1 33·0		1									1
33·1 37·0		1	1								2
37·1 41·0		1	2	3	2	3	2				13
41·1 45·0			1	3	8	8	6	2	1		29
45·1 49·0				2	2	6	8	2			20
49·1 53·0					2	7	6	3	3	1	22
53·1 57·0					1	3	3	1		1	9
57·1 61·0						1			1		2
F	1	3	4	8	15	28	25	8	5	2	99

CONTENTS

SUGARCANE BREEDING—INDICATIONS OF INHERITANCE.

BY

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(Received for publication on 2nd August 1926.)

I. Introduction.

In ordinary cultivation the sugarcane is propagated in the vegetative way, that is, from cuttings or *setts* as they are popularly called. Grown in this manner the crop largely resembles the planted cuttings except in the well known case of vegetative bud sports.

Sugarcanes frequently flower in the tropics; but, for a long time, it was not known that they produced fertile seeds. The fertility of cane seeds was first demonstrated in Java in the year 1887. Ever since that time, attempts are being made in almost every cane country to raise canes from seed with the definite object of producing seedlings superior to the cane varieties in cultivation. Grown from seed the resultant plants do not resemble one another or the parents even when precautions are taken against foreign pollination. Thus the ordinary type of "pure line" work with which all plant breeders are familiar, is impossible in the case of sugarcane and because of this, the sugarcane breeder obtains even in the first generation practically as many new seedling varieties as the number of seedlings grown. This places the breeding of sugarcanes in a class by itself and different from that of most other crops, where, with ordinary precautions against foreign pollination, the closest similarity is expected and actually found in the plants obtained.

Once a superior seedling is obtained from the very large number of types, it is subsequently multiplied for cultivation in the vegetative way from cuttings. It is this possibility of further multiplication in the vegetative way that renders possible any improvement of sugarcanes through breeding; without it the improvement obtained in a new seedling would soon be lost among the extensive variations in the second generation from seed. The vegetative multiplication further preserves the original characters of the new seedling under cultivation for fairly long periods. Experience has been recorded elsewhere to the effect that new seedlings obtained through breeding deteriorate quicker than the well known older varieties. This is not such a great disadvantage, as would at first sight appear, since in practice the continual production of new seedlings at the breeding stations results in the

canes which have already been issued, being replaced before they have had time to deteriorate appreciably under cultivation.

While the wide variations among the seedlings of the same parentage is one of the first experiences of the cane breeder during the earlier stages of his work, a family likeness among the seedlings of the same parentage soon forces itself on his attention as the work develops. Such a likeness is quickly noticed when seedlings from a large number of parents are grown side by side in the field. In certain cases a likeness is noticed without being able to indicate exactly the character or group of characters in which the resemblance is found.

The noticed variations are often so wide as to render seemingly unlikely any definite laws in the matter of inheritance in the sugarcane. A writer in the *Agricultural News*[1] "is of the opinion that attempts to synthesize new strains along Mendelian lines....would be almost certain to be barren of results" in the sugarcane. Similar variations are noticed in certain of the other vegetatively propagated crops as well, though the reason is yet obscure. In the case of the sugarcane, the opinion has been held in certain quarters that the wide variations result from the parent varieties being complex hybrids.

II. Certain difficulties in the study of inheritance in the sugarcane.

The study of inheritance in the sugarcane presents certain special difficulties resulting from the peculiarities of the plant. The more important of these are mentioned below :—

(*a*) Special care is needed to grow canes from seed ; as already mentioned the usual method of propagation is from cuttings.

(*b*) The occurrence of great variations among seedlings of the same parent, even when precautions are taken against foreign pollination. This throws doubt on the purity of the varieties employed.

(*c*) The uncertainty in the matter of parentage of most batches of even artificially raised seedlings resulting from the inability to employ either emasculation or bagging in cane breeding operations. The minuteness and delicacy of the floral structures in the sugarcane renders emasculation both difficult and laborious ; the bagging of the flowers against unintended pollen has been found to exert an adverse influence on the seed setting of the enclosed arrows.[2]

(*d*) A thorough knowledge of the mode of inheritance and segregation of characters requires a continuous study of more than one generation from seed ; this is often impossible in the cane, either on account of the non-flowering of the hybrids or the infertility of the flowers, when the hybrids do flower.

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[1] *Agri. News*, 3rd Feby. 1912, p. 33.

[2] Venkatraman T. S. Sugarcane Breeding in India—Hybridization to testing. *Agri. Jour. India*, Vol. XX, Pt. 3, pp. 175-177.

In spite of the above inherent difficulties, however, the rather large number of seedlings raised, and the variety of combinations employed at the Imperial Sugarcane-breeding station at Coimbatore, have yielded definite indications as to the inheritance of characters in the sugarcane. It is true that the inheritance herein recorded lacks the precision that has now come to be associated with similar studies in the case of most other crops; but in the face of the inherent difficulties above mentioned, a greater precision cannot reasonably be expected. The indications of inheritance mentioned below have been of considerable use in the breeding of canes in India; and, as such, it has been thought desirable to collect together whatever data has accumulated on the subject.

Tables of results given in support of the various statements made in the text do not represent the whole of the available data; it has been thought sufficient to present the typical cases alone, thus avoiding the overburdening of the tables.

III. Characters studied.

(1) Vigour of growth.

This is a character of importance in the cane and is one of the chief factors responsible for the total tonnage of cane in the field. Sugarcane varieties show considerable differences in the general vigour of the seedlings obtained from them, some of the Coimbatore seedlings being rather remarkable in the vigour of growth shown by their progeny.

When, therefore, it is desired to introduce vigour into a batch of seedlings which is otherwise satisfactory, the particular parent is crossed with varieties or seedlings which, it is known, do produce seedlings of marked vigour. It often happens, however, that the cross introduces along with the vigour certain other undesirable characters; but the wide variations obtained in the resultant population sometimes gives the desired combination, if the cross is raised on a sufficiently large scale.

The weight of the whole plant at harvest is an index of this character and the improvement in vigour obtained by a suitable cross pollination is seen from the table below.

Table I.

Influence of pollinating parent on the vigour of resultant seedlings.

Parentage of seedlings	Number of seedlings studied	Average weight of seedlings at harvest in lb.
Vellai × Striped Maur.*	39	52
Vellai × Ashy Maur.	67	49
Vellai × (Indian cane × *Sacch. Spont*)	87	103

*In this and other tables 'Maur.' is a contraction for 'Mauritius.'

Ashy Mauritius and Striped Mauritius are tropical canes producing seedlings of medium vigour ; the *Sacch. spontaneum* hybrid produces seedlings with marked vigour of growth.

(2) Habit of plant.

Some data on the inheritance of this character was presented in a previous publication from this station.[1] Certain varieties produce seedlings which show a markedly depressed habit in the earlier stages of growth, while those from others are fairly erect. Pollination with varieties of the former class often results in the development of a markedly depressed habit in the early stages of the resultant seedlings (Pl. I Figs. 1 and 2).

(3) Tillering.

The tillering character of a variety, on which depends the total number of canes produced, varies in different varieties. The Indian canes and certain of the Coimbatore seedlings possess a larger number of tillers than the tropical canes ; seedlings from the former class show a relatively larger number of tillers (Table II). Table III illustrates the influence of the pollinating parent.

Table II.

The relative tillering in seedlings from tropical and Indian canes.

Variety	Number of seedlings studied	Average number of tillers per seedling at harvest
Local striped (Tropical cane)	463	13
Local red (Tropical cane)	343	12
Saretha (Indian cane)	700	27

Table III.

Influence of pollinating parent on tillering.

Parentage	Number of seedlings studied	Average number of tillers per seedling at harvest
Vellai × tropical cane	159	14
Vellai × Co. 292	79	23

[1] Vittal Rao, U. Habit in sugarcanes. *Agri. Jour. India*, Vol. XV, Pt. 4, p. 418.

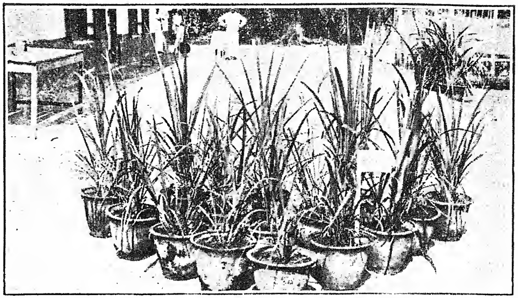

Fig. 1. Vellai × Variety producing erect seedlings

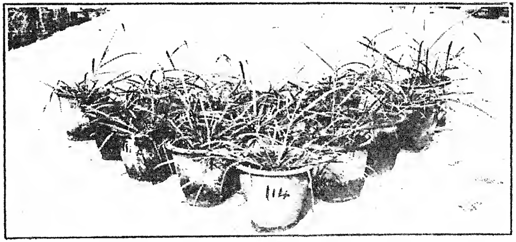

Fig. 2. Vellai × Variety producing depressed seedlings

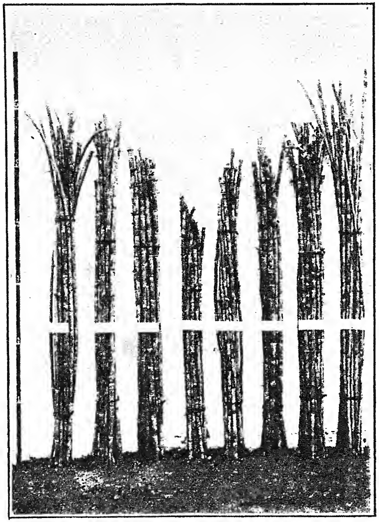

Fig. 3. P.O.J. 213 Hybrids

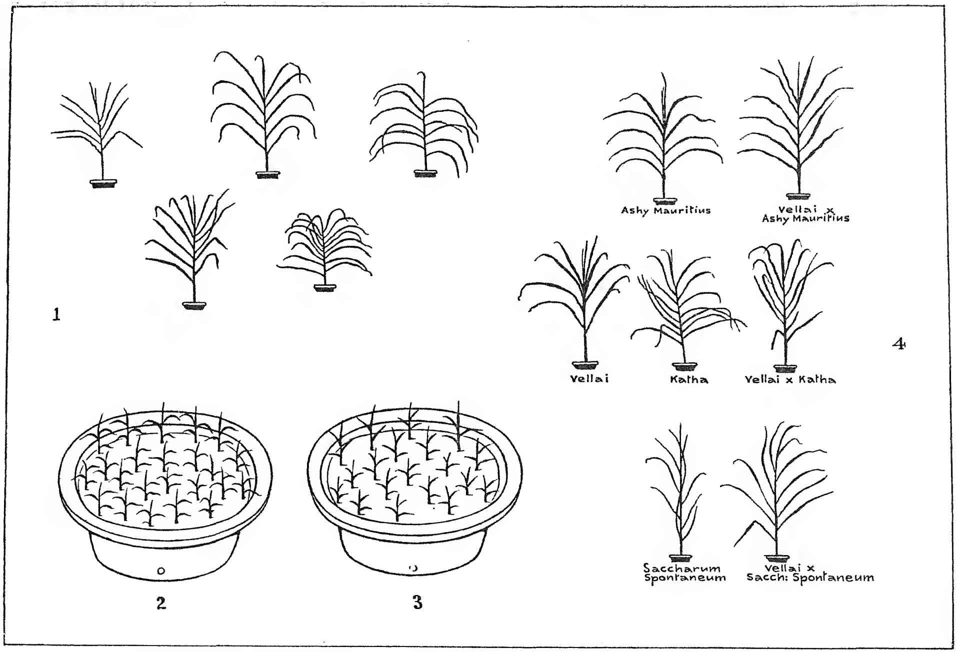

Fig. 1. Certain types of leaf tips met with in the sugarcane.
Fig. 2. Young seedlings of Mauritius 1237.
Fig. 3. Young seedlings; Mauritius 1237× Saretha, F. 1. generation. The leaf tips in Saretha are more erect than in Maur. 1237.
Fig. 4. Illustrates the influence of the pollinating parent on the leaf widh of the resultant seedlings.

Co. 292 is a hybrid between an Indian cane and *Sacch. spontaneum* and possesses a large number of tillers.

Tillering is a character of importance in cane and received considerable attention at the hands of Dr. C. A. Barber, C.I.E.[1] In certain recent root studies by the writer, a definite correlation has been found to exist between good tillering and an early and rapid development of the shoot roots after the germination of the setts.

It has further been found that the early depressed habit in certain canes directly helps in the tillering by bringing the first formed shoots into close contact with surrounding soil, thus accelerating the development of buds from these shoots.

In a cane plant the tonnage of canes at harvest depends on two factors, *viz.*, (1) number of tillers in the stool and (2) weight of individual canes. In certain localities—like the Northern Circars of the Madras Presidency—where conditions obtain, militating against the development of a deep root system and high winds prevail, it would appear desirable to secure the tonnage rather by a larger number of short canes to the stool than by a smaller number of taller canes. Indications are not wanting that such types could be produced by a suitable mating of parents. Mauritius seedling 1237 has been found useful in working to this type.

(4) Leaf characters.

(a) *Width.* One striking difference between tropical and Indian canes lies in their relative leaf widths. For cultivation in sub-tropical India, the broader leafed kinds have been found to be comparatively unsuitable. The narrower leafed forms are generally hardier and more resistant to drought and other adverse conditions. In the Punjab, where the conditions of growth are perhaps the least favourable in India, the successful seedling canes have all been from the narrow leaf class. As we proceed eastwards or southwards from that province, conditions of growth for cane steadily improve and the relatively broader leafed productions from Coimbatore have found their use in such tracts.

This character was recorded by measuring the maximum leaf widths in ten healthy shoots of the plant at harvest and averaging the total.* Table IV gives the relative leaf widths of seedlings derived from tropical and Indian canes. Table V and Plate II, Fig. 4 illustrate the influence of the pollinating parent.

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[1] Barber, C. A. Studies in Indian sugarcane, No. 4, Tillering or underground branching. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. X, No. 2.

* The methods for recording this and certain other morphological characters mentioned in the paper were originally developed by Dr. C. A. Barber, C.I.E.

TABLE IV.

Leaf widths of seedlings from tropical and Indian canes.

Variety		Number of seedlings studied	Average maximum leaf width in inches of	
			Parent	Seedlings
B. 208	Tropical canes	217	3·0	2·7
Local striped	Tropical canes	492	2·2	2·3
Saretha (Indian cane)		132	1·0	1·1

TABLE V.

Influence of pollinating parent on leaf width.

Parentage	Number of seedlings studied	Average maximum leaf width in inches of		
		♀ parent	♂ parent	Seedlings
Maur. 1237 × Pansahi seedling	92	2·8	2·3	2·4
Maur. 1237 × Co. 292	92	2·8	0·7	2·0
Str. Maur. × Pansahi seedling	90	2·6	2·3	2·3
Str. Maur. × Co. 292	77	2·6	0·7	1·7

(b) *Leaf tips.* Sugarcanes sometimes show marked differences in the manner in which tips of young leaves stand out in the field (Pl. II, Fig. 1). This character, though easily noticed in a field, has been found to be rather difficult for a detailed study ; the prevailing winds often break the tips or deviate them from their original positions. This character is sometimes very noticeable in the nurseries and has given indications as to the parentage of a batch of artificially crossed seedlings (Pl. II, Figs. 2 and 3). In the absence of such an early indication the seedlings would need to be grown to maturity for deciding if the intended cross has been effected.

(c) *Colour of leaf sheath.* Cane varieties differ from one another in the colour of their leaf sheaths. This character is sometimes rather difficult to describe on account of (1) the blending of more than one colour in the same sheath, (2) the

presence of blotches, here and there, of colours different from the main colour of the sheath and (3) alteration in colour with exposure.

In the study of this character for inheritance the main colour of the sheath has been taken for the classification. The Indian canes have the leaf sheaths more or less green ; and cross pollinations with these have been found to introduce a large parentage of green sheaths in the resultant population.

TABLE VI.

Inheritance of leaf sheath colour.

Variety	Number of seedlings studied	LEAF SHEATH COLOUR OF	
		Parent	Seedlings
Local red (Tropical cane) .	314	Purple.	91·2 per cent purple or vinous 8·8 per cent green.
Saretha (Indian cane) . .	1,000	Green.	4·0 per cent coloured other than green. 96·0 per cent green.

TABLE VII.

Influence of pollinating parent on leaf sheath colour.

Parentage	Number of seedlings studied	LEAF SHEATH COLOUR OF		
		♀ parent	♂ parent	Seedlings
Vellai × Co. 206 .	160	Pale green .	Other than green.	88·2 per cent coloured other than green. 11·8 per cent green.
Vellai × Co. 292 .	101	Do. .	Green .	50·0 per cent coloured other than green. 50·0 per cent green.
P. O. J. 213 × Co. 291	85	Pink or vinous	Other than green.	78·0 per cent other than green. 22·0 per cent green.
P. O. J. 213 × Saretha	76	Do. .	Green .	29·0 per cent other than green. 71·(per cent green.

(d) *Ligular process.* These are scarious extensions of the leaf sheath generally pointing and tapering towards the apex of the lamina. They may be long or short,

broad or narrow, tooth-like or sharp pointed, present on one or both sides, curved, merely indicated or altogether absent (Pl. III, Fig. 1). They are fairly conspicuous and have been of use in separating out varieties which are otherwise alike.

TABLE VIII.

Inheritance of ligular process.

Variety	Number of seedlings studied	CHARACTER OF THE LIGULAR PROCESS		
		In parent	In seedlings	
			% present one or both sides	% indicated or absent
Mauritius 90	88	Present one side.	95	5
Green sport	83	Do. .	83	17
Mauritius 55	71	Indicated or absent.	22·5	77·5

TABLE IX.

Influence of pollinating parent on ligular process.

Parentage	Number of seedlings studied	CHARACTER OF THE LIGULAR PROCESS IN			
		♀ parent	♂ parent	Seedlings	
				% present one or both sides	% indicated or absent
P. O. J. 213 × Co. 205 .	58	Present one side.	Present both sides.	93	7
P. O. J. 213 × Co. 292 .	186	Do. .	Indicated or absent.	71·4	28·6

(5) CHARACTERS OF THE CANE.

(a) *Thickness.* Cane varieties vary widely in thickness ranging from less than half an inch to as much as over two inches. The Indian canes are comparatively

Character variations in Sugarcane

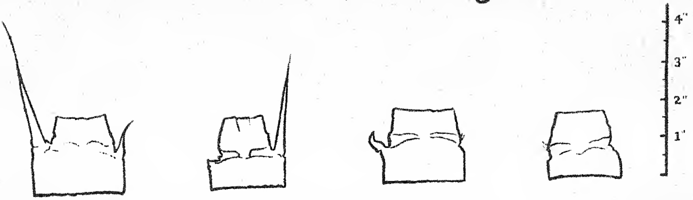


Fig. 1 Ligular Process

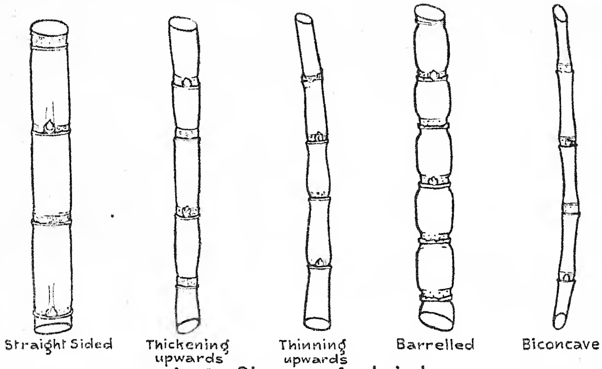
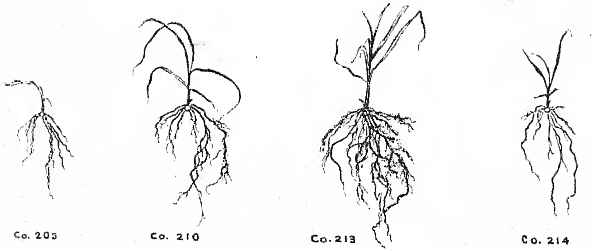


Fig. 2 Shape of Joint



(7 weeks from planting)

Fig. 3 Root Systems

thinner than the tropical kinds. In arriving at a figure for representing the thickness of cane in a clump, the following difficulties were experienced :—

(i) Variations in thickness among the individual canes of the same clump. There is, sometimes, a considerable difference between the early and late formed canes, the former being generally distinctly thinner than the latter. The varieties belonging to the Pansahi group of Indian canes are very characteristic in this respect ;

(ii) Variations between the top, middle and bottom portions of the same cane, the place of greatest thickness varying in different varieties ;

(iii) Variations between the different portions of the same joint, depending on its shape ;

(iv) Variations according as the measurements are taken in the plane of buds or at right angles to it. Canes which are oval in cross-section show a difference between the two measurements.

Measurements for this character were recorded by laying together at harvest all the canes from the clump and measuring the average specimen as judged by the eye.

TABLE X.

Inheritance of thickness of cane:

Variety	No. of seedlings studied	Average thickness of parent in cm.	PERCENTAGE OF SEEDLINGS WITH THICKNESS IN CM. FROM						
			1·0 to 1·4	1·5 to 1·9	2·0 to 2·4	2·5 to 2·9	3·0 to 3·4	3·5 to 3·9	4·0 to 4·4
Local red	317	3·0	..	..	3·4	22·3	35·0	26·8	12·5
Kaludai Boothan . .	154	2·8	..	..	1·8	22·4	50·0	20·3	5·5
Saretha . . .	87	1·6	13·9	65·2	20·9	..	..	..	..

TABLE XI.

Influence of pollinating parent on thickness of cane.

Parentage	No. of seedlings studied	AVERAGE THICKNESS OF		PERCENTAGE OF SEEDLING WITH THICKNESS IN CM. FROM				
		♀ Parent	♂ Parent	1·4 to 1·6	1·7 to 1·9	2·0 to 2·3	2·4 to 2·6	2·7 to 2·9
P. O. J. 213 × Katha . .	45	2·3	1·4	15·5	42·3	35·6	6·6	..
P. O. J. 213 × Saretha . .	65	2·3	1·6	3·0	26·2	49·3	16·9	4·5
P. O. J. 213 × Maur. 55 . .	40	2·3	3·4	5·0	10·0	50·0	20·0	15·0

(b) *Length.* Measurements have been recorded on the length of millable canes at harvest. Combined with habit, this character determines the height of the clumps in a variety. It is best studied by cutting out all the canes, laying them together and selecting an average specimen for measurement.

Till very recently the typically dwarf Indian canes did not set seed, and the seedlings obtained have largely been from parents not very widely differing from one another in height. Plate I, fig. 3 represents the harvest from an interesting set of crosses with P. O. J. 213 as the female parent. This series of crosses is of special interest, because P. O. J. 213 does not produce fertile pollen of its own; this rules out largely chances of selfed seedlings in the resultant population. The pollinating parent for the central bundle in the picture was Kansar, known to produce comparatively short seedlings. The bundles on either side have, as pollinating parents, varieties in an ascending order in height.

(c) *Shape of joint.* This is a character in which cane varieties show interesting difference (Pl. III, fig. 2). The shape of joint varies according as it is viewed in the plane of the bud or at right angles to it; the shapes in the accompanying tables were recorded with the buds towards the observer. Other things being equal, the shape of joint must have an effect on tonnage of cane; a barrelled joint, for instance, would yield more material for crushing than a bi-concave joint for the same length of cane. This character is best recorded by examining together all the canes cut from the clump; this rules out variations among the individual canes and the different parts of the same cane which are not uncommon.

TABLE XII.

Inheritance of shape of joint.

Variety	No. of seedlings studied	Shape of joint in parent	Percentage of seedlings with different shaped joints			
			Practically straight	Thickening upwards	Thinning upwards	Biconcave
Local red	362	Practically straight.	98	2	..	..
Local striped	228	Do.	97	..	1	2
Ashy Maur	82	Thickening upwards	23	77	..	..

TABLE XIII.

Influence of pollinating parent on shape of joint.

Parentage	No. of seedlings studied	Shape of joint in		
		♀ Parent	♂ Parent	Seedlings
Vellai × Str. Maur. .	68	Practically straight.	Practically straight.	None of the seedlings had joints thickening upwards.
Vellai × Ashy Maur. .	120	Do. .	Thickening upwards.	40·0 per cent. of the seedlings showed joints thickening upwards.
P. O. J. 213 × Maur. 55 .	40	Barrelled .	Barrelled .	Barrelled 96·5 per cent. Biconcave 3·5 per cent.
P. O. J. 213 × Katha .	45	Do. .	Biconcave .	Barrelled 80·0 per cent. Biconcave 20·0 per cent.
P. O. J. 213 × Saretha .	95	Do. .	Do. .	Barrelled 74·0 per cent. Biconcave 26·0 per cent.

(d) *Ivory or corky markings.* Certain varieties show on the joints long thin lines, grey or corky in colour, not unlike those found on ivory. Their presence and distribution is characteristic of certain varieties and has been of use in classifying varieties.

TABLE XIV.

Inheritance of ivory markings.

Variety	No. of seedlings studied	Ivory markings in parent	Percentage of seedlings in which ivory markings are	
			Present	Absent
Maur. 55	71	Absent	4	96
Maur. 90	88	Present ; moderate amount .	62	38
Saretha	80	Present ; abundant on root zone.	90	10

TABLE XV.

Influence of pollinating parent on ivory markings.

Parentage	No. of seedlings studied	IVORY MARKINGS IN		PERCENTAGE OF SEEDLINGS IN WHICH IVORY MARKINGS ARE	
		♀ Parent	♂ Parent	Present	Absent
P. O. J. 213 × Co. 291 .	184	Present .	Absent .	60	40
P. O. J. 213 × Co. 206 .	57	Present .	Present .	100	..
Green sport* selfed .	83	Occasional .	Occasional. .	31·5	68·5
Green sport × Katha .	48	Occasional .	Present .	89·6	10·4

(e) *Splits.* A break in the rind of a more serious nature is associated with what are termed *splits.* These sometimes extend inside to asmuch as half the thickness of the cane.

TABLE XVI.

Inheritance of splits.

Variety	No. of seedlings studied	Splits in parent	PERCENTAGE OF SEEDLINGS IN WHICH SPLITS ARE	
			Present	Absent
Maur. 55	71	Absent	5	95
Green sport	83	Rare	36	64
Naanal	100	Present	67	33

TABLE XVII.

Influence of pollinating parent on splits.

Parentage	No. of seedlings studied	SPLITS IN		PERCENTAGE OF SEEDLINGS IN WHICH SPLITS ARE	
		♀ Parent	♂ Parent	Present	Absent
P. O. J. 213 × Co. 291 .	200	Present .	Absent .	55	45
P. O. J. 213 × Co. 206 .	40	Present .	Present .	90	10

* This is a bud sport from Striped Mauritius.

(f) *Circlet of hairs.* At the nodes and immediately beneath the bases of leaf sheaths certain canes, chiefly the Indian kinds, show a vestiture of hairs of varying length, number and colour. Like some of its predecessors this character often varies not only in the different canes of the same clump but also in different parts of the same cane. It is best recorded at harvest after a bulk examination of all the canes in the clump.

TABLE XVIII.

Inheritance of circlet of hairs.

Variety	No. of seedlings studied	Circlet in parent	Percentage of seedlings in which circlets are	
			Present	Absent
Kaludai Boothan . .	120	Absent	2	98
Green sport . . .	90	Absent	..	100
Saretha . . .	100	Present	92	8

TABLE XIX.

Influence of pollinating parent on circlet of hairs.

Parentage	No. of seedlings studied	Circlet in		Percentage of seedlings in which circlets are	
		♀ Parent	♂ Parent	Present	Absent
P. O. J. 213×Katha .	50	Indicated .	Present .	80	20
P. O. J. 213×Kansar .	200	Indicated .	Present .	60	40
P. O. J. 213×Maur. 55 .	50	Indicated .	Absent .	18	82
P. O. J. 213×Co. 206 .	200	Indicated .	Absent .	2	98

(6) Characters of the root.

The study of rooting is of importance in all agricultural crops. The soil and hence the roots constitute the chief medium through which environmental factors act on a crop ; and the character of the root system gives valuable indications as to locality and conditions where a particular variety would do its best. Certain canes show characteristic differences in the roots (Pl. III, Fig. 3) ; and a knowledge of these is often of use in deciding the places to which to distribute the canes. The soil excavations needed in connection with root studies are both laborious and expensive ; and it has not been possible yet to collect sufficient data to present the inheritance in the form of tables.

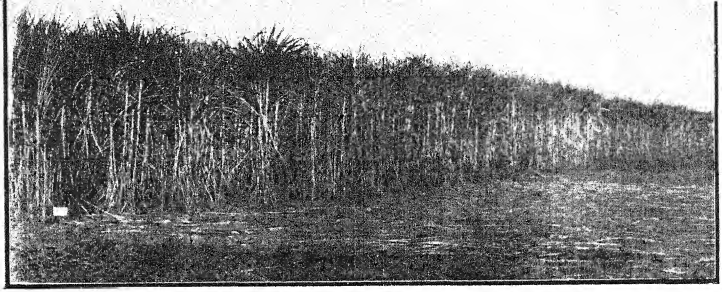
(a) *Depth.* The tropical canes are, on the whole, characterized by a comparatively shallow root system. This character appears to be largely responsible for the poor performance of most canes of this class under field conditions in Northern India. Some of the Indian canes, as also *Saccharum spontaneum*, possess a deep root system. From the very inception of cane breeding work at Coimbatore, sugarcanes have frequently been crossed with *Saccharum spontaneum* ; and the hybrid seedlings have shown a comparatively deeper root system apparently derived from the grass. Such seedlings have found their use under conditions of limited soil moisture (Pl. IV, Fig. 1). It has further been found that hybrids of the same variety with different parents show differences in consonance with the root systems of the parents employed (Pl. V).

(b) *Penetration through stiff soils.* Investigations recently undertaken by the writer to ascertain the causes for the failure of certain canes in stiff soils have indicated a difference in the relative powers of penetration by the roots. The studies were made by causing the two halves of the roots from the same plant to develop in two different pots, one filled with stiff soil and the other with sand. Roots of tropical canes are weaker in this respect than those of certain Indian kinds and *Saccharum spontaneum* possesses this ability in a marked degree (Pl. VI). *Saccharum spontaneum* has been found to have an appreciable influence on hybrids raised with this as one of the parents. The seedling Coimbatore 205 now popular in the Punjab—a cross between a tropical cane and *Saccharum spontaneum*—is one example of this inheritance.

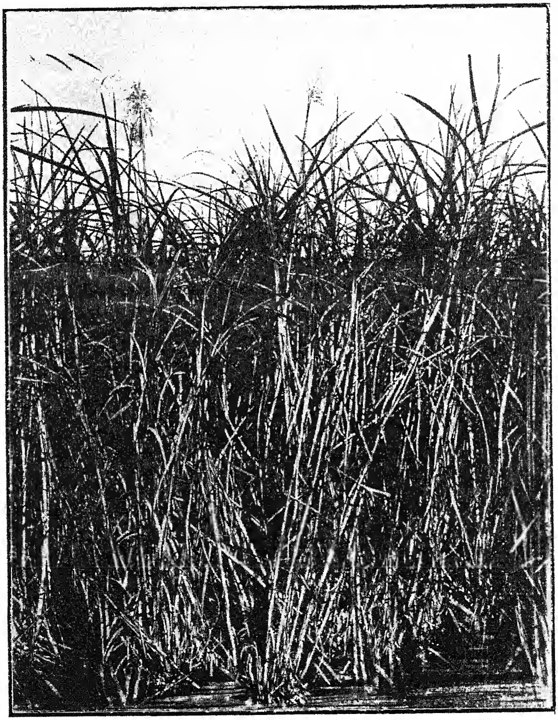
(c) *Resistance to waterlogging.* Another important characteristic of *Saccharum spontaneum* is its ability to " endure bad soil-aeration "[1] and thus thrive under waterlogged conditions. The seedling Co. 205 has shown remarkable powers in this respect (Pl. IV, Fig. 2).

(d) *Other characters.* Other characters in which indications of inheritance have been noticed include (*i*) time and rapidity of root development, (*ii*) length of func-

[1] R. S. Hole. Some Indian forest grasses and their Oecology. *Ind. Forest Mem., Bot. Ser.,* Vol. I, pt. 1, p. 115.

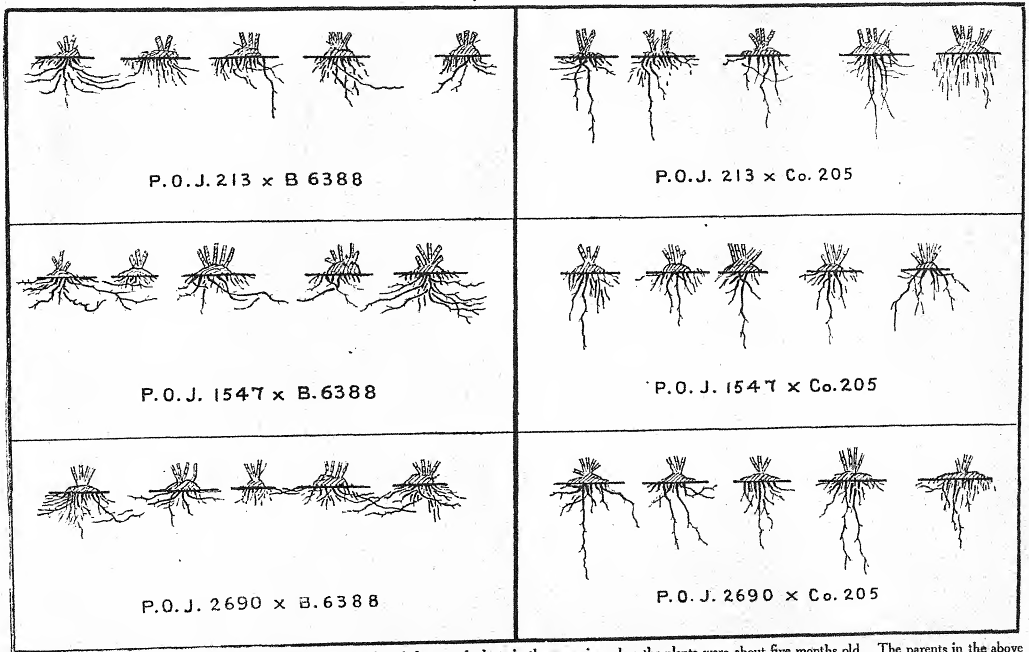


Co. 205 grown without irrigation at the Government Farm, Gurdaspur (Punjab). It yields about 50 per cent. more *gur* (raw sugar) than the local canes.



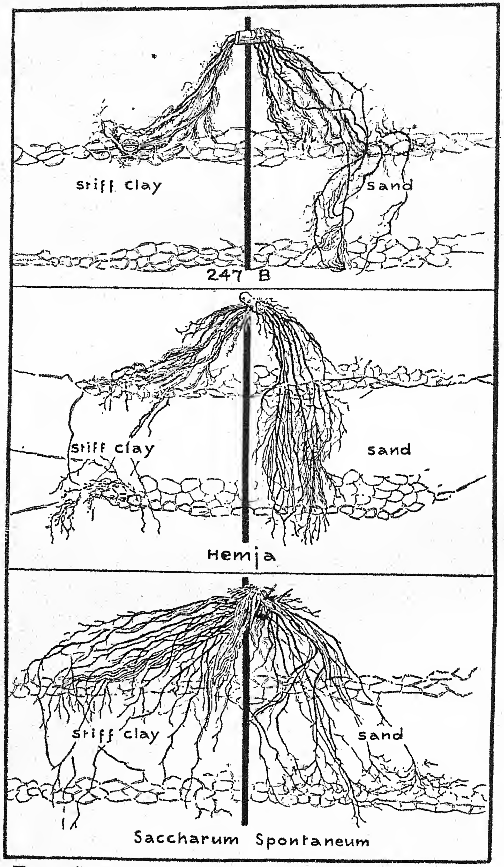
Co. 205 grown in a ryot's field under swamp conditions. It yields in such conditions also about 50 per cent. more *gur* (raw sugar) than the local canes.

Root systems of Hybrid seedlings



The above sketches were recorded after dissecting the roots of a whole row of plants in the nurseries, when the plants were about five months old. The parents in the above crosses are all shallow rooted as compared with Co. 205. Note the difference in depth of root according as the same variety is crossed with B, 6388 or with the comparatively deeper rooting Co. 205.

Soils and Root Development



The above line drawings were made from photographs recorded when the plants were a little over two months old. The central vertical line in the pictures indicates the partition between stiff clay and sand. The two horizontal layers of wire netting are intended to catch the roots in their original positions, as they develop through the meshes. The layers of netting are one foot apart.

tioning period of sett and shoot roots and (*iii*) periodicity in the development of shoot roots.

(7) Character of the juice.

The quality and quantity of juice obtained are characters of importance as they have a direct influence on the quality and quantity of the finished product. Impure juices give rise to various difficulties in the subsequent processes of manufacture into sugar. Sugarcane hybrids with *Saccharum spontaneum* as one of the parents frequently show considerable impurities in the juice apparently derived from the grass. It has therefore often been found necessary to cross these again with canes of good juice quality for obtaining satisfactory juice in the seedlings.

Though as many as about 50,000 analyses are now available for studying the inheritance of this character, the bulk of them had to be rejected as not quite comparable on account of (*i*) differences in methods of sampling, (*ii*) differences in time of analyses and (*iii*) seasonal variations from year to year. Though there are wide variations in juice quality between the individual seedlings of the same parent, it is found that the average quality of all the seedlings varies according to the parent (Table XX). When two different varieties are crossed with each other, the average juice quality of the hybrids is intermediate between those of the parents (Table XXI).

Table XX.

Inheritance of juice quality.

Variety	No. of seedlings studied	Percentage of sucrose in juice	
		parent	average of seedlings
B. 208	109	18·5	17·5
66. White Carp	138	18·4	17·7
Local striped	310	14·8	14·3
Khena	51	11·6	8·6
Kassoer	10	8·9	8·6

TABLE XXI.

Juice quality of hybrid seedlings.

Parentage	No. of seedlings studied	Percentage of sucrose in juice		
		♀ Parent	♂ Parent	Average of seedlings
Vellai × Ashy Maur. . . .	87	15·8	16·1	15·9
Vellai × Sacch. spont. . . .	38	15·8	5·0	11·4

(8) SUSCEPTIBILITY TO SMUT.

Susceptibility to " smut " appears to be a group character in the Indian canes. Varieties of the Saretha group are very susceptible, while those of the Mungo group do not generally get it (Table XXII).

TABLE XXII.

Occurrence of " smut " in the different groups of Indian canes.

Group	No. of varieties studied in the group	Percentage of varieties noted as susceptible
Mungo	39	..
Pansahi	21	10
Sunnabile	23	12
Nargori	17	65
Saretha	23	72

A very large number of seedlings have been raised from the canes of the Saretha group as they both flower and set seed profusely at Coimbatore. Such seedlings have been found to be particularly susceptible to the disease. The Indian cane " Chunnee " pelongs to this group ; and the Java hybrids with this as one of the parents have shown a distinct susceptibility.

P. O. J. 213 shows about 8 per cent. smut in the fields at Coimbatore. This variety is infertile in pollen. Cross pollinated with different varieties the hybrids have shown smut in consonance with the susceptibility of the pollinating parent (Table XXIII).

TABLE XXIII.

Influence of pollinating parent on susceptibility in seedlings.

Percentage of smutted plants in		
P. O. J. 213	Pollinating parent	Hybrid seedlings
	7	1·7
	8	3·2
8	10	3·0
	20	5·0
	60	12·0

Hybrids with *Saccharum spontaneum* have been noticed to be generally not susceptible to smut.

IV. Summary and conclusion.

(1) Though considerable variations are noticed in seedlings obtained from the same parent, a certain amount of family likeness among them is observed on a closer and wider examination.

(2) Certain of the chief difficulties in the study of inheritance in the sugarcane are mentioned.

(3) Data are presented which indicate an inheritance of characters in the sugarcane. The characters studied include (*a*) general characters of the plant in the field, (*b*) certain morphological characters of the leaf and cane, (*c*) physiological and habit characters of the root, (*d*) characters of the juice, and (*e*) susceptibility to smut.

(4) The indications of inheritance, though lacking in the definiteness now associated with such studies, have yet been of value in the achievement of certain practical results, *viz.*, the production, through hybridization, of improved seedlings for cultivation in sub-tropical India.

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CONTENTS

STUDIES IN GUJARAT COTTONS, PART IV.

HYBRIDS BETWEEN *BROACH-DESHI* AND *GOGHARI* VARIETIES OF *GOSSYPIUM HERBACEUM*.

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In previous Memoirs[1] the characters of the three main varieties (*Broach-deshi*, *Goghari*, and *Wagad*) of *Gossypium herbaceum* as grown in Gujarat have been described, and an account of a number of representative strains has been given. The first variety (*Broach-deshi*), taken generally, is characterized by a fairly long staple, and by a relatively low ginning percentage, while the second (*Goghari*) usually gives a short staple rough cotton, which possesses a high ginning percentage. The advantage which would accrue if the longer staple of the best strains of the former could be combined with the high ginning of the latter was obvious, and soon after pure strains had been definitely isolated, the crossing of suitable pure types was undertaken in 1919-20. This crossing has not only led to types with the combination of characters desired, but has provided a considerable amount of interesting material relative to their behaviour on crossing, of which it is proposed to give an account in the present Memoir.

I. The material for crossing.

The general characters of *Goghari* cotton given in the author's previous Memoir were based on the types as grown at Broach. These differ slightly when strains of this cotton are grown at Surat, thirty miles further south, and with a generally more moist and longer season. The following description of the types used are from the material actually employed for crossing as grown at Surat where the work was done.

[1] *Mem. Dept. Agri. India, Bot. Ser.*, Vol. XI, No. 4 (1921); Vol. XII, No. 5, 1924; and Vol. XIV, No. 2, 1926.

BROACH-DESHI TYPES. Two of the pure types, isolated by the author, were used as follows :—

1. *Type 10.7A. L. F.* This type is valued not only because it has the longest staple of any hitherto isolated from Gujarat cottons, but also because of the silky character of its fibres and their creamy colour. The plants of this strain are of a bushy character, but the first fruiting branch is found at a comparatively high node (16 to 20) on the main stem. The leaves are particularly dark green and leathery, at the beginning of the cold weather. The bolls are large and tapering, and the boll index * is, hence, low compared with other types. It usually lies between 75 and 80.

The length of the lint varies in different years from 22½ to 29 millimeters, but in any year it is always higher by from 7 to 12 millimeters than the *Goghari* type with which it is crossed. The lint index ranges from 30 to 35 milligrammes per 100 seeds, and the ginning percentage has varied during a series of six years from 33·5 to 37·0 per cent.

2. *Type I. A. Cylindrical Boll.* This strain of cotton has special value because of its high and constant yield, its high ginning percentage, and its good staple.

The plants are more bushy than any other *Broach-deshi* strain isolated, and it has more markedly hairy leaves. The first fruiting branch is found practically at the same level as in 1027 A. L. F.—about the 16th to the 20th node on the main stem. The bolls are cylindrical, that is to say, they taper only slightly and the boll index varies from 80 to 84.

The length of the lint varies in different years from 19½ to 26½ millimeters, but in any year it is always higher by from 4 to 7 millimeters than the *Goghari* type with which it is crossed. The lint index ranges from 35½ to 41½ milligrammes per 100 seeds, and the ginning percentage has varied from 37 to 39 per cent. in a series of six years.

GOGHARI TYPE. The crossing was done with one single *Goghari* type, which was chosen simply on account of its abnormally high ginning percentage, which in fact varies from 46 to 51 per cent.

This *Goghari* type is not a very bushy strain. The primary fruiting branches are very vigorous; and are borne at a very low point on the main stem, that is to say, at between the 14th and 17th node. The bolls are almost round with a boll-index of from 87 to 91.

The length of the lint is very low, varying from 13½ to 19½ millimeters, and hence the cotton is very inferior. The lint index ranges from 46 to 60 milligrammes per 100 seeds, and the ginning percentage has varied (as already stated) from 46 to 51 per cent. In this matter of ginning percentage, the figure is higher than any known strain of *Gossypium herbaceum.*

It will be seen from these descriptions that we have two very markedly different kinds of cotton plant, and a study of the actual figures during the last six years

* The boll-index is the maximum diameter × 100 divided by the maximum length of the bolls.

for the types to be crossed reveals the fact that between either of the *Broach-deshi* parents and the *Goghari* parent, there is a significant difference in the following characters :—

1. The node on the main stem from which the first sympodium arises.
2. The number of monopodia on the main stem.
3. The greatest diameter of the bolls.
4. The boll-index.
5. The length of staple on the middle of the seed.
6. The lint index.
7. The seed weight (only in the case of 1-A cylindrical Boll and Goghari).
8. The ginning percentage.

The other characters in which these types differ are (*a*) the extent of opening of the bolls, which is very difficult to measure satisfactorily, (*b*) the fuzziness or nakedness of the seed surface, in which the difference is, in any case, one of degree, but which varies from boll to boll, and (*c*) the way in which the lint hairs are strongly or loosely attached to the seeds. No attempt was made to study these characters statistically.

II. The characters of the hybrid plants.

There has been much study of the results of crossing among cottons , but most of these have been of crosses made between different species of *Gossypium*. Thus the results of crossing *Gossypium barbadense* (Sea Island cotton) and *Gossypium hirsutum* (Upland American) on the one hand, and *Gossypium peruvianum* (Egyptian) and Upland American have been carefully studied. In India we have the studies by Leake[1] of crosses of *Gossypium neglectum* with *Gossypium arboreum* and *Gossypium indicum*, and by Kottur[2] of a cross between *Gossypium neglectum* and *Gossypium herbaceum* (Kumpta cotton). Little is known, on the other hand, of the behaviour of crosses between types within the same species. Studies have, however, been made by Kearney[3] in Egyptian cottons and by Longfield[4] in Sea Island cottons as grown in the West Indies.

The original crosses on which the results to be described are based were made in 1919-20. The male parent in each case was the Goghari E-5, the female being the *Broach-deshi* 1027 A. L. F. or I-A. Cylindrical Boll. Since 1920-21, the parents have been always grown side by side with the various generations of the cross. In the first generation (F_1) four dibbles from each crossed boll were planted,

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[1] Leake and Ram Prasad. Studies in Indian cottons. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. VI. No. 4 (1914).

[2] Kottur. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. XII, No. 3 (1923).

[3] Kearney. A study of hybirds in Egyptian cotton. *Amer. Nat.*, Vol. 52, p. 491 (1918).

[4] Longfield. Experiments with hybird cottons. *Rep. Agri. Expt. Station St. Croix*, 1913 -14 (1915)

and it was soon evident that considerably greater vigour had resulted in the plants. This was shown in the height of the plant and in the development of the branches, resulting in high yield. The actual figures of the yield of seed-cotton from one hundred and twenty dibbles were as follows :—

	Yield of seed cotton in lb. per 120 dibbles (3′ × 3′).
1027 A. L. F	13·7
I-A Cylindrical Boll	15·2
Goghari E-5	11·9
1027 × E-5	17·2
I-A × E-5	17·3

No new extra-parental characters were observed in the progeny of the crosses and no sterility was seen. No individual plant in the second generation of the cross (F_2) was seen which varied *widely* from the type of either parent.

A. The node on the main stem from which the first sympodium arises.

The importance of this vegetative character is considerable, as it determines in some measure the type of plant which ultimately grows. But it is manifestly dependent very largely on the environmental conditions of any year, and it is far more variable in any pure strain in one season than another. The mean figure for the mean node number for the three strains used as parents of the cross and the co-efficient of variation is shown below :—

Mean node number of parents of the cross.

Year	1027 A. L. F.		I-A Cylindrical Boll.		Goghari E-5.	
	Mean node number	Coefficient of variation	Mean node number	Coefficient of variation	Mean node number	Coefficient of variation
1920-21	15	13·0±0·6	15	11·0±0·3	..	..
1921-22	20	7·6±0·3	20	6·0±0·3	17	7·9±0·5
1922-23	16	9·6±0·4	17	8·1±0·3	14	16·5±0·6*
1923-24	17	8·9±0·4	17	8·2±0·4	14	10·3±0·5
1924-25	17	12·9±0·5	17	11·2±0·4	14	14·9±0·5
1925-26	17	9·6±0·4	17	8·2±0·3	14	9·9±0·4

It is evident from these figures that the difference between the *Broach-deshi* types used as female parents and the *Goghari E-5* used as the male parent, in this

* An irregularly germinated crop.

matter is significant, and it is interesting to follow the behaviour of the character when they are crossed. It is curious to note the much greater variation shown each year by the *Goghari* strain than by the others.

Details as to the behaviour of this character in the first generation of the cross (F_1) was wanting, but the second generation (F_2) shows a very wide variation. The following table gives a frequency distribution of the progeny in each case, compared with that of the parents of the crosses, so far as the node number of the first sympodium is concerned. The figures are taken for 500 plants in each case.

Frequency of each node number.

Node number	1027 A. L. F.	1-A Cylindrical boll	Goghari E-5	1027 × Goghari cross	1-A × Goghari cross
13-14	..	..	9	4	..
15-16	18	..	136	78	68
17-18	61	90	**255**	**259**	**277**
19-20	**225**	**320**	100	136	**133**
21-22	175	90	..	21	22
23-24	21	..	..	2	—

The mean node number in each case was in 1921-22 (for the parents and the second generation of the cross).

1027 A.L.F.	20·4
1-A Cylindrical boll	19·5
Goghari E-5	17·4
1027 × Goghari cross	17·9
1-A × Goghari cross	17·2

Out of the progeny, the seed from two or three plants self-fertilized were continued in the third generation. They were selected not on account of the character, now under discussion, but because of their seed and fibre characters. The plants selected had node numbers as follows :—

1027 × Goghari cross—	
Plant 5	18
Plant 6	18
1 A × Goghari cross—	
Plant 1	18
Plant 5	17
Plant 9	**19**

B

Their progeny in 1922-23 gave the following distribution for 100 plants in each case, the figures for the parents also being given.

NODE NUMBERS.

Frequency distribution with different types.

	9-10	11-12	13-14	15-16	17-18	19-20
1027 A. L. F.	..	7	11	45	17	..
1-A Cylindrical boll	..	1	2	15	60	22
Goghari E-5	11	21	9	52	6	..
1027 × Goghari cross—						
Plant 5	2	34	2	36	26	..
Plant 6	..	6	6	71	17	..
1-A × Goghari cross—						
Plant 1	1	21	20	27	29	2
Plant 5	4	10	29	53	4	..
Plant 9	..	..	4	67	29	..

One plant out of each type of the cross was now selected for propagation in the next generation, the plants selected having node numbers as follows :—

1027 A. L. F. × Goghari cross—

Plant 5	15
Plant 6	17

1-A × Goghari cross—

Plant 1	15
Plant 5	16
Plant 9	15

Again, the progeny of these plants gave the following distribution for 100 plants in each case, in the fourth generation of the cross.

Node numbers.

Frequency distribution with different types.

	11-12	13-14	15-16	17-18	19-20
1027 A. L. F.	..	7	38	**46**	9
1-A Cylindrical boll	..	6	**46**	37	11
Goghari E-5	5	**44**	39	12	..
1027 × Goghari cross—					
Plant 5	5	19	**47**	24	5
Plant 6	..	11	**54**	33	2
1-A × Goghari cross—					
Plant 1	2	34	**55**	9	..
Plant 5	3	17	**58**	21	1
Plant 9	7	27	**57**	9	..

Similar selection of a single plant has been done for the two following generations with results as follows :—

FIFTH GENERATION. (F_5).

A. Node number of plant selected as parent.

1027 × Goghari cross—

Plant 5 15

Plant 6 18

1-A × Goghari cross—

Plant 1 16

Plant 5 16

Plant 6 14

B. NODE NUMBERS OF PROGENY.

Frequency distribution with different types.

	9-10	11-12	13-14	15-16	17-18	19-20	21-22	23-24	25-26
1027 A. L. F.	..	3	11	23	37	23	3	..	..
1-A Cylindrical boll	..	1	5	21	40	27	6	..	..
Goghari E-5	3	19	25	29	23	1	..	..	..
1027 × Goghari cross—									
Plant 5	..	4	4	31	44	17	..	..	..
Plant 6	..	2	10	27	48	12	1	..	..
1-A × Goghari cross—									
Plant 1	..	1	9	26	59	13	1	..	..
Plant 5	..	..	..	..	7	20	50	18	5
Plant 9	2	4	26	44	22	2	..	..	..

SIXTH GENERATION. (F_6).

A. NODE NUMBER OF PLANT SELECTED AS PARENT.

1027 × Goghari cross—

Plant 5 16

Plant 6 16

1-A × Goghari cross—

Plant 1 . . . . Not available (Pruned).

Plant 5 22

Plant 6 . . . . Not available (Pruned).

B. NODE NUMBERS OF PROGENY.

Frequency distribution with different types.

	7-8	9-10	11-12	13-14	15-16	17-18	19-20	21-22	23-24
1027 A. L. F.	..	..	2	4	30	52	11	1	..
1-A Cylindrical boll	..	..	..	2	30	51	16	1	..
Goghari E.-5	1	4	31	53	10	1	..	..	..
1027 × Goghari cross—									
Plant 5	..	..	1	21	48	29	1	..	..
Plant 6	..	..	1	15	51	29	4	..	..
1-A × Goghari cross—									
Plant 1	..	..	..	15	60	22	3	..	..
Plant 5	..	..	..	..	3	26	53	16	2
Plant 9	..	1	7	63	25	4	..	..	..

It will be seen that while there is full evidence of the hereditary nature of the character in question, it is only in the fifth and sixth generation (F_5 and F_6) of the cross that we have been able to separate types, by the method adopted, which breed true, that is to say, which give progeny *not more variable than the original parents*. This has, however, been reached in all cases now, as is shown by the following mean figures in the two years, with the coefficient of variation :—

	1924-25		1925-26	
	Mean node number	Coefficient of variation	Mean node number	Coefficient of variation
1027 A. L. F.	16·9	12·9±0·5	16·8	9·6±0·4
1-A Cylindrical boll	17·5	11·2±0·4	17·1	8·2±0·3
Goghari E-5	14·5	14·9±0·6	14·0	9·9±0·4
1027 × Goghari cross— Plant 5	16·8	10·3±0·7	15·7	9·9±0·3
Plant 6	16·6	10·3±0·5	16·0	9·1±0·4
1-A × Goghari cross— Plant 1	16·8	10·3±0·5	15·7	8·5±0·3
Plant 5	21·4	8·4±0·4	19·2	7·8±0·5
Plant 9	15·2	11·8±0·5	13·9	9·0±0·3

These figures show that of the five selections made in the F_2 generation and continued by single plant selections in succeeding generations all have ceased splitting and breed true by the test used. Of these

(1) Three have the same node number as the female parent (1027 A. L. F. or 1-A Cylindrical Boll as the case may be) *viz.* (Plants 5 and 6 of the 1027 × Goghari cross and Plant 1 of the 1-A × Goghari cross);

(2) One has the same node number as the male parent (Goghari E-5). This is Plant 9 of the 1-A × Goghari cross.

(3) One gives higher values than either of the parents (Plant 5 of the 1-A × Goghari cross) and has done so from the fifth generation (F_5).

The last is an interesting case, and of some importance. It shows that we are dealing with a complex character, and it is possible that this is one of the cases where the theory of cumulative factors might serve to explain the results. Further, as in lower Gujarat it is rather an advantage for the first sympodial branch to be high (so as to leave ample chance for a satisfactory development of primary monopodia), it shows that the method followed is capable of leading to improved types, as in the case of the plant in question.

B. The greatest diameter of the bolls.

The size of the bolls is important in every type of cotton, and other things being equal, the type which has the largest bolls will always be preferred. The difference between the average of the determinations of the maximum diameter of the bolls of the parents of the cross is significant, and is shown in various years in the following table.

Greatest diameter of the bolls.

	1027 A. L. F.		1-A Cylindrical Boll.		Goghari E-5	
	Mean	Coefficient of variation	Mean	Coefficient of variation	Mean	Coefficient of variation
	mm.		mm.		mm.	
1921-22	25·9	3·0±0·2	25·2	2·5±0·2	28·6	3·1±0·3
1922-23	26·5	3·3±0·3	..	..	28·5	2·9±0·2
1923-24	27·1	2·2±0·1	25·3	3·0±0·2	28·5	2·6±0·2
1924-25	28·1	3·5±0·2	26·8	3·6±0·2	29·2	3·6±0·2
1925-26	25·4	3·5±0·2	25·2	3·0±0·1	27·0	2·8±0·1

Details of the behaviour of this character in the first generation of the cross (F_1) are wanting, but the second generation shows very wide variation. The following table gives a frequency in each case, compared with that of the parents of the crosses. The figures are given for 100 plants in each case.

Frequency distribution with each type.

	1027 A. L. F.	1-A Cylindrical boll	Goghari E-5	1027 × Goghari cross	1-A × Goghari cross
Diameter in mm.—					
23-24	..	3	..	..	1
24-25	15	33	..	3	4
25-26	36	**58**	..	12	18
26-27	**46**	6	3	**32**	**37**
27-28	3	..	18	29	27
28-29	..	..	**49**	19	11
29-30	..	..	24	3	2
30-31	..	..	6	1	..

The mean diameter in each case was, in 1921-22, for the F_2 generation.

	mm.
1027 A. L. F.	25·9
1-A Cylindrical boll	25·2
Goghari E-5	28·6
1027 × Goghari cross	27·1
1-A × Goghari cross	26·8

The distribution in the F_2 generation in the frequency table given above is almost a normal frequency curve (suggesting a complex character); the range covers the extrêmes of both parents, and there is very little overlapping between the figures obtained with the two parents.

The selections—two plants of the 1027 × Goghari cross, and three plants of the 1-A × Goghari cross—were treated exactly as described previously, and the behaviour of single plant selections in the succeeding generations is shown below.

THIRD GENERATION (F_3).

In this generation only the 1-A × Goghari cross was studied, and the figures for 1-A Cylindrical boll are missing. The figures obtained were, however, as follows :—

1. Diameter of bolls of the parent plants.

	mm.
1-A × Goghari cross—	
Plant No. 1	28
Plant No. 5	27

2. Maximum boll diameter (in mm.).

Frequency distribution with different types.

	24-25	25-26	26-27	27-28	28-29	29-30	30-31
Goghari E-5	..	..	..	30	40	27	3
1-A × Goghari cross—							
Plant 1	..	13	51	26	10	..	..
Plant 5	2	6	27	43	19	3	3

FOURTH GENERATION (F_4).

1. Diameter of bolls of the parent plants.

	mm.
1-A × Goghari cross—	
Plant 1	28
Plant 5	26

The others were not recorded.

2. Maximum boll diameter in mm.

Frequency distribution with different types.

	23-24	24-25	25-26	26-27	27-28	28-29	29-30	30-31
1027 A. L. F. . .	5	23	56	16	..	..	..	..
1-A Cylindrical boll .	5	23	39	23	10	..	..	..
Goghari E-5 . .	..	..	..	1	25	51	23	..
1027 × Goghari cross—								
Plant 6 . . .	..	..	..	..	7	38	41	14
1-A × Goghari cross—								
Plant 1 . . .	..	2	2	25	41	28	2	
Plant 9 . . .	3	12	22	28	27	8	..	

FIFTH GENERATION (F_5).

1. Diameter of bolls of the parent plants.

	mm.
1027 × Goghari cross—	
Plant 6	28
1-A × Goghari cross—	
Plant 9	26

The others were not recorded.

2. Maximum boll diameter (in mm.)

Frequency distribution with different types.

	24-25	25-26	26-27	27-28	28-29	29-30	30-31	31-32	32-33	33-34
1027 A. L. F. . .	..	..	9	38	39	11	2	1	..	..
1-A Cylindrical boll .	4	14	44	29	8	1	..	..	..	..
Goghari E.-5 . .	..	..	..	16	28	34	10	3	..	..
1027 × Goghari cross—										
Plant 6 . .	..	..	..	2	8	31	37	14	6	7
1-A × Goghari cross—										
Plant 1 . .	2	5	26	53	14	..	..	..	..	..
Plant 5 . .	..	2	7	19	37	26	8	1	..	..
Plant 9 . .	..	1	5	39	45	9	1	..	..	..

SIXTH GENERATION (F_6).

1. Diameter of bolls of the parent plants.

	mm.
1027 × Goghari cross—	
Plant 6	28
1-A × Goghari cross—	
Plant 1	29
Plant 5	30
Plant 9	28

2. Maximum boll diameter (in mm.)

Frequency distribution.

	23-24	24-25	25-26	26-27	27-28	28-29	29-30	30-31
1027 A. L. F.	8	19	47	25	1	..	..	..
1-A Cylindrical boll	5	31	51	13	..	..	..	..
Goghari E.-5	..	1	5	45	42	7	..	..
1027 × Goghari cross—								
Plant 5	..	..	13	43	40	4	..	..
Plant 6	..	..	..	4	29	47	19	1
1-A × Goghari cross—								
Plant 5	1	12	25	51	11	..	..	..
Plant 9	..	6	35	43	11	..	..	..

We have again been able to separate types in the fifth and sixth generations of the cross, which breed true and whose variability seems to have reached a stable position. The mean values and the coefficient of variation for the three final years are given below :—

	1923-24		1924-25		1925-26	
	Mean diameter mm.	Coefficient of variation	Mean diameter mm.	Coefficient of variation	Mean diameter mm.	Coefficient of variation
1027 A. L. F.	25·4	2·3±0·1	2[illegible]·1	3·6±0·2	25·4	3·6±0·2
1-A Cylindrical boll	25·7	2·9±0·2	26·8	3·6±0·2	25·2	3·0±0·1
Goghari E-5	28·5	2·6±0·2	29·2	3·6±0·2	27·0	2·8±0·1
1027 × Goghari cross— Plant 5	..	..	..	..	26·8	2·9±0·8
Plant 6	29·3	3·7±0·3	30·3	3·9±0·3	28·4	2·8±0·2
1-A × Goghari cross— Plant 1	27·5	3·4±0·2	27·2	3·2±0·2	..	..
Plant 5	..	..	28·6	4·4±0·3	26·1	5·0±0·2
Plant 9	26·4	4·7±0·4	28·1	3·0±0·2	26·2	2·9±0·1

These figures show that of the five selections made in the F_2 generation, and continued by single plant selections in succeeding generations, four have now come to breed true, while one is still doubtful by the test used. Of these,

(1) One has the same type as the female parent (1-A × Goghari cross plant 1).
(2) One has the same type as the male parent (1027 × Goghari cross plant 5).
(3) One shows a higher value than either parent (Plant 6 of the 1027 × Goghari cross).
(4) Two show types intermediate between the two parents, *viz.*, 1-A cross plants 5 and 9 out of which the purity of the former is still doubtful.

It may, therefore, be concluded that the character under study is hereditary, but is, again, a complex one, because of the occurrence of a segregate with a higher value than either parent.

C. Shape of bolls.

The question as to whether the shape of bolls is hereditary, that is to say, whether a round bolled type of cotton or a long-bolled type gives progeny true to this character, is one which has been many times studied. The figure used as an indication of shape is the boll index, or, in other words, the relation of the maximum breadth of the boll to its length. It will be seen that a high boll index means a *round* boll; a low boll index means a *long* boll.

Studying the shape of the bolls by the use of this boll index, Kearney[1] found that in a cross between an Egyptian (Pima) and an Upland American (Holdon) cotton, the character was a complex one composed of more than one hereditary factor, but the same worker[2], when investigating a cross between two Egyptian cottons (Gila and Pima) showed that the F_2 generation was not more variable than the F_1 generation, and thus the shape of the boll was not inherited as a Mendelian character at all. This seemed also to be confirmed by the behaviour in the F_3 generation. In Upland-Egyptian cotton hybrids, Balls[3] found a similar result to that of Kearney noted above. McLendon,[4] working with Upland-Sea-Island hybrids, concluded that the short thick type of boll is recessive, although he did not find the long slender type to be fully dominant.

Apart from its scientific interest, the shape of the boll is important to us as a means of rapidly identifying a type of cotton, and so its behaviour on crossing has a very special interest. The actual figures for the mean boll index in the parents of the cross under study, with the variability as shown by the coefficient of variation is shown in the following table.

[1] Kearney. Segregation and correlation of characters in an Upland-Egyptian cotton hybrid. *U. S. A. Dept. Agri. Bull* 1164 (1923).

[2] Kearney. Hybrids in Egyptian cotton. *Am. Nat.*, Vol. 52 (1918).

[3] Balls. The cotton plant in Egypt, p. 162.

[4] McLendon. Mendelian inheritance in cotton hybrids. *Georgia Agri. Expt. Sta. Bull.* 99 (1912).

Boll index.

	1027 A. L. F.		1-A Cylindrical boll		Goghari E-5	
	Mean	Coefficient of variation	Mean	Coefficient of variation	Mean	Coefficient of variation
1921-22	75·0	3·0±0·3	80·9	2·9±0·2	90·7	2·1±0·2
1922-23	77·0	2·4±0·2	..	..	91·1	2·2±0·2
1923-24	77·0	2·1±0·1	80·4	1·5±0·1	86·8	2·6±0·2
1924-25	79·2	1·8±0·1	84·0	2·0±0·9	90·1	2·2±0·1
1925-26	76·5	2·5±0·1	82·7	2·0±0·1	89·7	2·9±0·1

There is thus a very marked difference between the shape of the bolls in the strains crossed, and the behaviour of the cross in the following generations may be followed. In the first generation (F_1) measurements of the character were not recorded, but in the second (F_2) generation the means and the coefficient of variation were as follows :—

Boll index—F_2 generation (1921-22).

	Mean value	Coefficient of variation
1027 A. L. F.	75·0	3·0±0·3
1-A Cylindrical boll	80·9	2·9±0·2
Goghari E-5	90·7	2·1±0·2
1027 × Goghari cross	84·9	4·3±0·1
1-A × Goghari cross	85·7	4·0±0·1

The mean figures for the crossed types are very nearly the average of the parental values,—though the 1027 × Goghari cross goes a little towards greater diameter. The coefficient of variation is, however, considerably higher than that of either parent, as would be expected with the segregation of a hereditary character.

D

The distribution of the value of this boll index in the F_2 generation is shown below :—

Frequency of boll index value.

	1027 A. L. F.	1-A Cylindrical boll	Goghari E-5	1027 × Goghari cross	1-A × Goghari cross
68-72	6	..	..	1	..
72-76	52	3	..		..
76-80	42	30	..	9	5
80-84	..	61	..	30	27
84-88	..	6	3	43	45
88-92	..	..	73	15	19
92-96	..	..	24	2	4

There is no overlapping between the values for the boll-index in the parents of the 1027 × Goghari cross, and it is only slight between those of the 1-A × Goghari cross. If we take these values below 86 as characteristic of one parent, and those over this figure as characteristic of the other, the figures work out as follows: —

1027 × Goghari cross—

Ratio.— $\dfrac{\text{Low boll index}}{\text{High boll index}}$ . . . . $= \dfrac{1{\cdot}6}{1}$

1-A × Goghari cross—

Ratio.— $\dfrac{\text{Low boll index}}{\text{High boll index}}$ . . . . $= \dfrac{1{\cdot}15}{1}$

If these are combined, that is to say, if we consider the inheritance being similar in both cases, the ratio becomes :

$$\frac{\text{Low boll index}}{\text{High boll index}} = \frac{1{\cdot}36}{1}$$

or approximately a ratio of 9 to 7, which would be expected of a complex character with two independently varying factors.

In the succeeding generations, all the types obtained by taking selections from the F_2 generation, and single plant selections of each strain in the following years, go back into one or other of the parental types. . The records of the third generation (F_3) are not complete enough to enable us to use them.

FOURTH GENERATION (F_4).

1. Boll index of parent plants.

1-A × Goghari cross—
Plant 1 . . . . 93·0
Plant 9 . . . . 80·5

2. Boll index in F_4 generation.

Frequency distribution with different types.

	72-76	76-80	80-84	84-88	88-92
1027 A. L. F.	29	**69**	2	..	..
1-A Cylindrical boll	..	35	**65**	..	..
Goghari E-5	..	..	10	**54**	36
1027 × Goghari cross—					
Plant 6	..	9	**52**	37	2
1-A × Goghari cross—					
Plant 1	..	6	**61**	27	6
Plant 9	3	37	**54**	6	..

FIFTH GENERATION (F_5).

1. Boll index of parent plants.

1027 × Goghari cross—
Plant 6 85

1-A × Goghari cross—
Plant 1 . . . . . 82·5
Plant 9 . . . . 79·5

2. Boll Index in F_5 generation.

Frequency distribution with different types.

	72-76	76-80	80-84	84-88	88-92	92-96
1927 A. L. F.	1	73	26	..	..	..
1-A Cylindrical boll	..	1	45	53	1	..
Goghari E.-5	..	..	..	14	67	19
1027 × Goghari cross— Plant 6	..	9	59	28	4	..
1-A × Goghari cross— Plant 1	..	7	52	36	5	..
Plant 5	..	..	1	16	51	32
Plant 9	..	6	73	21	..	..

SIXTH GENERATION (F_6).

1. Boll index of parent plants.

1027 × Goghari cross—	
Plant 6	78
1-A × Goghari cross—	
Plant 1	80·5
Plant 5	96·0
Plant 9	83·0

2. Boll index in F_6 generation.

Frequency distribution with different types.

	72-76	76-80	80-84	84-88	88-92	92-96
1027 A. L. F.	36	56	8	..	..	..
1-A Cylindrical boll	..	5	71	24	..	..
Goghari E-5	..	..	..	30	48	22
1027 × Goghari cross— Plant 5	2	34		8	..	..
Plant 6	17	72	11	..	..	..
1-A × Goghari cross— Plant 5	..	..	4	19	68	9
Plant 9	..	..	20	57	23	..

On a review of all these figures, it may be stated that there is evidence that the shape of the boll, as indicated by the boll index, is a complex character as already found by both Kearney and Balls. It would seem that it may be composed of two factors.

The further growth of selfed material up to the sixth generation of the cross, shows that the progeny ultimately falls into one or other of the parental types. This is apparently due to the proportionate increase or decrease in both the components of the ratio, *viz.* greater diameter and length of bolls. Out of five cases studied, four had become closely similar to the female parent, with similar variability, and one had approximated to the male parent. The following is a statement of the mean values of the parents and of the final three years of the growing of the cross.

	1923-24		1924-25		1925-26	
	Mean boll index	Coefficient of variation	Mean boll index	Coefficient of variation	Mean boll index	Coefficient of variation
1027 A. L. F.	77·0	2·1 ±0·1	79·2	1·8±0·1	76·5	2·5±0·1
1-A Cylindrical boll	80·4	1·5±0·1	84·0	2·0±0·1	82·7	2·0±0·1
Goghari E-5	86·8	2·6±0·2	90·2	2·2±0·1	89·7	3·0±0·1
1027 × Goghari cross— Plant 5	..	..	..	..	80·8	2·9±0·1
Plant 6	79·3	2·8±0·1	83·1	3·1±0·2	77·8	2·6±0·1
1-A × Goghari cross— Plant 1	82·9	2·6±0·2	83·5	3·1±0·2	..	..
Plant 5	..	..	90·5	2·7±0·1	89·3	2·7±0·1
Plant 9	80·4	2·7±0·1	83·4	2·2±0·1	86·1	2·5±0·1

D. Length of staple.

In breeding cotton for the market, the length of the staple becomes one of the dominating considerations, and hence any evidence obtainable as to the nature of this character, and how it behaves in breeding is of very great importance, and many studies have been made upon it. Most of the early workers in India found that long staple is dominant over short staple, and that it behaves as a simple Mendelian character. The results of Fletcher, Fyson, and Kottur agree with this view.[1] McLendon,[2] studying Sea Island Upland hybrids, found no pure dominance, as the first generation (F_1) gave a type intermediate between the parents, and variable. Kearney,[3] studying hybrids between Egyptian (Pima) and Upland (Holdon) cottons, found that the F_1 generation gave staple intermediate between

[1] Fletcher. Mendelian inheritance in cotton. *Journal Agricultural Science*, Vol. II, p. 281 (1907).

Fyson. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. II, No. 6 (1908).

Kottur. Studies of inheritance in cotton, Part I. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. XII, No. 3 (1923).

[2] McLendon. Mendelian inheritance in cotton hybrids. *Georgia Agri. Expt. Stn. Bull.* 99 (1912).

[3] Kearney. Segregation and correlation of characters in an Upland-Egyptian cotton hybrid. *U. S. A. Dept. Agri. Bull.* 1164 (1923).

the parents, but approached that of the longer parent, while the distribution of the progeny in the F_2 generation indicated that several factors were involved.

Thus the net conclusion from previous work is that while long staple tends to be a dominant character, yet recent investigation suggests that this dominance is not complete, and that the character may be decidedly a complex one.

In the records which follow, the staple was always determined on the middle of the seed, and from ten seeds taken from three bolls representing the whole produce of a plant. The actual figures for the parents, in this character, for a series of years, with the coefficient of variation are as follows :—

LENGTH OF STAPLE.

	1027 A. L. F.		1-A CYLINDRICAL BOLL		GOGHARI E-5	
	Mean mm.	Coefficient of variation	Mean mm.	Coefficient of variation	Mean mm.	Coefficient of variation
1920-21	26	8·7±0·4	22	10·0±0·5	18	12·0±0·6
1921-22	29	7·2±0·6	26	7·2±0·3	20	9·4±0·6
1922-23	29	6·7±0·6	24	8·5±0·4	17	10·8±0·5
1923-24	22	10·1±0·4	20	9·7±0·3	14	11·5±0·4
1924-25	24	9·4±0·4	20	10·8±0·3	16	13·3±0·5
1925-26	23	8·8±0·1	21	8·7±0·1	13	13·2±1·0

This is one of the two characters, therefore, in which there is the greatest difference between the parents, the 1027 A.L.F. representing the best staple among Gujarat cottons while the Goghari E-5 was worthless as a staple cotton. In the first generation (F_1) of the crosses, the distribution and mean of the progeny is shown below.

LENGTH OF STAPLE. F_1 GENERATION.

Frequency distribution in percentage.

	10-12	13-15	16-18	19-21	22-24	25-27	28-30	31-33
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
1027 A. L. F. . .	..	..	..	3	29	46	20	2
1-A Cylindrical boll .	..	..	3	39	42	16	..	..
Goghari E-5 . .	2	12	42	44	..	..	..	..
1027 × Goghari cross .	..	..	..	10	66	23	1	..
1-A × Goghari cross .	..	2	28	55	14	1	..	..

The F_1 generation is therefore intermediate between the parents, as the means show—

LENGTH OF STAPLE. F_1 GENERATION.

	Mean	Coefficient of variation
	mm.	
1027 A. L. F.	26	$8 \cdot 7 \pm 0 \cdot 4$
1-A Cylindrical boll	22	$10 \cdot 0 \pm 0 \cdot 5$
Goghari E-5	18	$12 \cdot 0 \pm 0 \cdot 6$
1027 × Goghari cross	23	$7 \cdot 7 \pm 0 \cdot 2$
1-A × Goghari cross	20	$10 \cdot 2 \pm 0 \cdot 2$

The mean of the parents in the 1027 × Goghari cross is 22 and that of the 1-A × Goghari cross is 20, showing how nearly intermediate the F_1 generation is—

SECOND GENERATION (F_2).

The distribution of the value of the staple length in the second generation of the cross is as follows :—

Frequency of length of staple (1921-22).

Staple length mm.	1027 A. L. F.	1-A Cylindrical boll	Goghari E-5	1027 × Goghari cross	1-A × Goghari cross
13-15	..	..	..	..	4
16-18	..	..	22	4	27
19-21	..	1	68	22	41
22-24	..	14	10	40	23
25-27	20	60	..	31	5
28-30	60	23	..	3	..
31-33	17	22	..	..	..
34-36	3	..	..	..	..

The mean figure and the variability are as follows :—

LENGTH OF STAPLE. F_2 GENERATION.

	Mean	Coefficient of variability
1027 A. L. F.	29	7·2±0·6
1-A Cylindrical boll	26	7·2±0·3
Goghari E-5	20	9·4±0·6
1027 × Goghari cross	23	12·0±0·1
1-A × Goghari cross	20	14·2±0·1

The figures for plants selected as described under previous characters in the next four generations may now be given.

THIRD GENERATION (F_3).

(1) Staple of parent plants.

	mm.
1027 × Goghari cross—	
Plant 5	27
Plant 6	26
1-A × Goghari cross—	
Plant 1	24
Plant 5	23
Plant 9	25

(2) Staple Length in F_3 generation.

Frequency distribution with different types.

	13-15 mm.	16-18 mm.	19-21 mm.	22-24 mm.	25-27 mm.	28-30 mm.	31-33 mm.
1027 A. L. F.	..	..	..	..	17	60	23
1-A Cylindrical boll	..	1	9	47	42	1	..
Goghari E-5	23	63	14	..	..	..	..
1027 × Goghari cross— Plant 5	..	..	6	25	57	12	..
1-A × Goghari cross— Plant 1	1	15	44	33	7	..	..
Plant 5	1	8	28	45	18	..	..
Plant 9	..	1	11	35	45	8	..

FOURTH GENERATION (F_4).

(1) Staple of parent plants.

	mm.
1027 × Goghari cross—	
Plant 5	26
Plant 6	25
1-A × Goghari cross—	
Plant 1	24
Plant 5	24
Plant 9	24

2. Staple length in F_4 generation.

Frequency distribution.

	10-12 mm.	13-15 mm.	16-18 mm.	19-21 mm.	22-24 mm.	25-27 mm.
1027 A. L. F.	..	..	6	33	42	19
1-A Cylindrical boll	..	2	30	54	14	..
Goghari E-5	14	58	28	..	..	..
1027 × Goghari cross—						
Plant 6	..	2	11	42	39	6
1-A × Goghari cross—						
Plant 1	1	7	30	47	13	2
Plant 5	..	3	16	45	32	4
Plant 9	1	6	28	49	16	..

FIFTH GENERATION (F_5).

(1) Staple of parent plants.

	mm.
1027 × Goghari cross—	
Plant 5	23
Plant 6	23
1-A × Goghari cross—	
Plant 1	22
Plant 5	22
Plant 9	21

2. Staple length in F_5 generation.

Frequency distribution.

	10-12 mm.	13-15 mm.	16-18 mm.	19-21 mm.	22-24 mm.	25-27 mm.	28-30 mm.
1027 A. L. F.	..	..	2	18	36	43	1
1-A Cylindrical boll	..	1	17	57	23	2	..
Goghari E-5	4	36	40	20	..	..	..
1027 × Goghari cross—							
Plant 5	..	..	..	10	30	54	6
Plant 6	..	..	4	26	38	31	1
1-A × Goghari cross—							
Plant 1	..	..	2	33	45	20	..
Plant 5	..	1	14	52	31	2	..
Plant 9	..	..	8	48	38	6	..

SIXTH GENERATION (F_6).

(1) Staple of parent plants.

	mm.
1027 × Goghari cross—	
Plant 5	26
Plant 6	24
1-A × Goghari cross—	
Plant 1	24
Plant 5	22
Plant 9	23

2. Staple length in F_6 Generation.

Frequency distribution.

	7-9 mm.	10-12 mm.	13-15 mm.	16-18 mm.	19-21 mm.	22-24 mm.	25-27 mm.
1027 A. L. F.	..	..	..	2	28	55	15
1-A Cylindrical boll	..	..	1	12	57	29	1
Goghari E-5	2	25	60	13	..	..	..
1027 × Goghari cross— Plant 5	..	..	..	5	29	45	21
Plant 6	..	..	1	14	41	39	5
1-A × Goghari cross— Plant 1	..	..	..	7	47	41	5
Plant 5	..	..	..	12	54	32	2
Plant 9	..	..	..	9	47	40	4

Types have again been separated which breed true and whose variability seems to have reached a stable position. The mean values and the coefficient of variation for the two final years are given below.

	1924-25		1925-26	
	Mean staple length	Coefficient of variation	Mean staple length	Coefficient of variation
	mm.		mm.	
1027 A. L. F.	24	9·4±0·4	23	8·8±0·1
1-A Cylindrical boll	20	10·8±0·3	21	8·7±0·1
Goghari E-5	16	13·3±0·5	13	13·2±0·0
1027 × Goghari cross— Plant 5	25	8·6±0·2	22	11·0±0·1
Plant 6	23	11·3±0·2	21	12·2±0·0
1-A × Goghari cross— Plant 1	22	9·2±0·2	21	8·5±0·4
Plant 5	21	10·5±0·1	21	10·1±0·1
Plant 9	21	10·5±0·2	21	10·3±0·1

All the types isolated from the cross seem now to be pure so far as the purity can be judged by the coefficient of variation. The purity of the strain represented by 1027 × Goghari cross, Plant No. 5, was also tested by determining the correlation between parents and offspring in 44 plants of this type. The coefficient of correlation worked out at —0·004, which shows that there is no correlation and hence the strain is pure.

The purity in each case being clear, it will be noted that of the five types isolated—

(1) three conform almost exactly to the character of the longer staple parent (1027 × Goghari cross, Plant 5, and 1-A × Goghari cross, Plants 5 and 9).

(2) One is slightly inferior to the longer parent (1027 × Goghari cross, Plant 6).

(3) One is distinctly longer in staple than the longer parent (1-A × Goghari cross, Plant 1).

The occurrence of the types which do not conform to the character in either parent makes it very probable that length of staple is a complex character. Further evidence is probably needed to prove this point absolutely, but the facts here presented would make it very probable, and would be of great importance as they would open the possibility of breeding types with a much longer staple than that of either of the parents involved.

There is one point in connection with the staple of these crosses which has not yet been dealt with. The staple, as given, is that of the mean from the middle of the seed. But the cotton is actually a mixture of fibres of very different staple length. The actual proportion of fibres of different lengths, as determined by the Balls Sorter,* in 1924-25 for 1027 A. L. F., and some of the crosses was as follows :—

Frequency distribution.

Length of fibre	1027 A. L. F.	1027 × Goghari cross No. 6	1-A × No. 1	Goghari No. 5	Cross No. 9
mm.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
7·5	0·2	0·7	0·3	0·3	0·4
10·5	1·3	1·6	1·8	1·6	1·6
13·5	2·8	3·4	3·1	3·5	4·1
16·5	4·8	5·4	5·8	6·7	8·0
19·5	9·1	11·2	11·3	12·9	19·6
22·5	18·7	20·4	23·8	23·3	*25·7*
25·5	*36·7*	*31·7*	*36·0*	*27·6*	21·0
28·5	22·5	22·1	16·6	19·5	17·3
31·5	3·4	3·8	1·3	4·6	2·3
34·5	0·4	..	..	..	..
37·5	0·1	..	..	..	..

* The determinations were made in the Technological Laboratory of the Indian Central Cotton Committee, Bombay.

The results of spinning tests of some of these cottons, showing the highest counts of warp to which each could be spun economically (1924-25 season) with moderate twist were as under :—

Counts spun economically.

	s.
1027 A. L. F.	32
1027 × Goghari cross—	
No. 6	32
1-A × Goghari cross—	
No. 1	30
No. 5	22
No. 9	26

Similar results of some of these cottons from fifty pounds samples for 1925-26 were as under :—

Counts spun economically.

	s.
1027 A. L. F.	28
1027 × Goghari cross—	
No. 5	26
No. 6	20
1-A Cylindrical boll	20 barely
1-A Goghari cross, No. 9	20

The spinning power does not entirely correspond with the tests of staple, and this is not unexpected, as the capacity to spin fine yarn is not *exclusively*, even with the same class of cotton, dependent on the length of staple.

E. Weight per seed and its relation with lint length and lint index.

The importance of this character is indirect. But it has been shown in a previous memoir that in these Gujarat *herbaceum* cottons there is a positive correlation between the weight of the seed and the weight of the lint on the seed. It does not, however, seem to have been studied by previous workers, though Dunlavy[1] has found that, in Texas cottons, it is clearly correlated with other characters as follows :—

Coefficient of correlation.

Lint index and seed weight	$+0{\cdot}70 \pm 0{\cdot}021$
Boll size and seed weight	$+0{\cdot}66 \pm 0{\cdot}034$
Staple length and seed weight	$+0{\cdot}43 \pm 0{\cdot}043$
Lint percentage and seed weight	$-0{\cdot}53 \pm 0{\cdot}038$

[1] *Jour. American Soc. Agri.*, Vol. XV, No. 11 (1923).

The present study is only concerned with the cross made between our types 1-A Cylindrical Boll and Goghari E-5, as in the other case there is no significant difference between the seed weights of the parents. The actual mean figures given by the parents in this case and the coefficient of variation is shown in the following table.

Weight of seed.

	1-A Cylindrical boll		Goghari E-5	
	Mean	Coefficient of variation	Mean	Coefficient of variation
	mg.		mg.	
1919-20	59·7	5·5±0·37	53·7	7·2±0·34
1920-21	59·4	5·1±0·34	53·6*	..
1921-22	62·9	..	60·9	..
1925-26	59·5	8·9±0·42	53·8	11·1±0·45

The difference between the mean value of the seed weight in the parents is distinct and constant. The distribution of the seed weights in 100 plants of each type in 1920-21 and in the first two generations of the cross is as follows (1920-21 and 1921-22).

Frequency of seed weights.

Seed weights	1-A Cylindrical boll	Goghari E-5	Cross F_1	Cross F_2
mg.				
36—40	..	..	..	..
40—44	..	..	..	1
44—48	..	6	4	2
48—52	..	28	9	
52—56	12	38	27	9
56—60	50	24	47	27
60—64	31	3	11	32
64—68	7	..	2	19
68—72	..	1	..	7
72—76	..	..	..	3
76—80	..	..	..	
80—84	..	..	..	
88—92	..	..	..	
Means .	59·4 mg.	53·6 m.g.	60·2 mg.	61·5 mg.

* The seed weight of Goghari E-5 in 1920-21 is of the crop grown at Broach, not at Surat. As the seed weight of "1-A Cylindrical Boll" is the same at Surat in 1919-20 and 1920-21, it is assumed that this would also be the case with the other parent.

The figures for the F_2 generation are, of course, not quite comparable with the others, as they were not for the same season, and the frequency distribution for the parents in 1921-22 is not available. But the figures do show the somewhat wider distribution and nearly symmetrical curve which would be expected in the second generation of a cross with a complex character.* The fact that the seed weights of the parents overlap so considerably precludes Mendelian analysis but a study of what happens in succeeding generations, by method previously adopted, may give interesting results. The figures for the first (F_1) generation of the cross, however, show that the seed weight is much higher than the mean of the parents and hence indicates at least partial dominance.

The results in succeeding generations were as follows :—

Third Generation (F_3). (1) Seed weight of parent plants.

1-A × Goghari cross—	mgm.
Plant 1	72
Plant 5	62
Plant 9	67

(2) Seed weight in the F_3 generation—

Frequency distribution with different types.

	44-52 mg.	52-56 mg.	56-60 mg.	60-64 mg.	64-68 mg.	68-72 mg.	72 76 mg.	76-48 mg.	Mean mg.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
1-A Cylindrical boll	Not recorded								62·2
Goghari E 5									59·1
1-A × Goghari cross—									
Plant 1	1	2	12	35	34	12	3	1	64·0
Plant 5	7	17	33	26	12	3	2	..	59·6
Plant 9	..	..	8	18	32	29	10	3	66·9

Fourth Generation (F_4). (1) Seed weight of parent plants—

1-A × Goghari cross—	mg.
Plant 1	70
Plant 5	59
Plant 9	58

* The coefficient of variation in " 1-A Cylindrical Boll × Goghari Cross " in the F_1 and F_2 generations is as follows :—F_1—coefficient of variation $6{\cdot}5 \pm 0{\cdot}5$; F_2 Coefficient of variation $8{\cdot}5 \pm 0{\cdot}2$. It is slightly greater in the F_2 generation.

(2) Seed weight in the F_4 generation—

Frequency distribution with different types.

	48-52 mg.	52-56 mg.	56-60 mg.	60-64 mg.	64-68 mg.	68-72 mg.	72-76 mg.	76-84 mg.	Mean mg.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
1-A Cylindrical boll	Not recorded								66·0
Goghari E-5									60·0
1-A × Goghari cross—									
Plant 1	2	4	6	27	27	18	13	3	65·8
Plant 5	..	..	..	..	..	..	..	..	..
Plant 9	1	5	25	25	20	17	7	..	63·5

Fifth Generation (F_5). (1) Seed weight of parent plants—

	mg.
1-A × Goghari cross—	
Plant 1	66
Plant 5	61·5
Plant 9	58·5

(2) Seed weight in the F_5 generation.

Frequency distribution with different types.

	44-52 mg.	52-56 mg.	56-60 mg.	60-64 mg.	64-68 mg.	68-72 mg.	72-76 mg.	76-84 mg.	Mean mg.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
1-A Cylindrical boll	Not recorded								64·6
Goghari E-5									62·9
1-A × Goghari cross—									
Plant 1	..	10	5	41	33	7	2	2	63·8
Plant 5	17	32	42	8	..	1	..	..	55·5
Plant 9	3	22	58	9	7	..	1	..	58·2

Sixth generation (F_6). (1) Seed weight of parent plants—

	mg.
1-A × Goghari cross—	
Plant 1	60
Plant 5	53
Plant 9	60

(2) Seed weight in the F_6 generation.

Frequency distribution with different types.

	32-36 mg.	36-40 mg.	40-44 mg.	44-48 mg.	48-52 mg.	52-56 mg.	56-60 mg.	60-64 mg.	64-68 mg.	Mean mg.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
1-A Cylindrical boll .	1	..	..	1	4	9	20	47	8	59·5
Goghari E-5 . .	2	2	..	9	23	27	22	13	2	53·8
1-A × Goghari cross—										
Plant 1 . .	..	..	..	..	..	..	..	..	..	60·3
Plant 5 . .	2	9	13	29	34	4	9	..	..	51·2
Plant 9 . .	..	11	5	19	50	14	1	..	..	52·1

The mean values and the coefficients of variation in the last three generations will show how far clearly distinct types have been obtained. They are as follows :—

	1923-24		1924-25		1925-26	
	Mean seed weight	Coefficient of variation	Mean seed weight	Coefficient of variation	Mean seed weight	Coefficient of variation
	mg.		mg.		mg.	
1-A Cylindrical boll	·66	..	65	..	59·5	8·9±0·4
Goghari E-5	60	..	63	..	54	11·1±0·4
1-A × Goghari cross—						
Plant 1	66	9·0±0·4	64	8·2±0·6	60	..
Plant 5	..	..	55·5	7·3±0 3	51	10·4± 0·5
Plant 9	63·5	8·6±0·4	58	6·4±0·4	52	9·0±0·3

Three conclusions with regard to the inheritance of seed weight seem to follow from this analysis of the record of these plants. They are :—

1. There appears at least partial dominance[1] in the direction of heavier seed weight as the F_1 generation shows considerable departure from the mean of the parents towards the heavier seeded variety.

2. The coefficient of variation in the F_1 generation is less than in the more varying parent, as well as in the F_2 generation ; though the difference is slight. Further, the distribution in the F_2 generation is nearly symmetrical. All these facts indicate that we are dealing with a complex character involving several-factors.[2]

3. By the F_5 and F_6 generation all the types obtained have a coefficient of variation lower than that of the parents, and may hence be taker as pure for this

[1] Kearney. Segregation and correlation of characters in an Upland-Egyptian cotton hybrid. *U. S. A. Dept. Agri. Bull.* 1164 (1923), p. 53.
[2] East. Studies in size inheritance in Nicotiana. *Genetics*, Vol. I, p. 164 (1916).

character. It will be noticed that the progeny of plant No. 1 has regained almost exactly the position of the parent 1-A Cylindrical boll; the progeny of plants 5 and 9, on the other hand, gave in two successive generations *below* the figure for the Goghari E-5 parent. The latter fact is of particular interest, as it may show possibilities of achieving a break up of this character, enabling us to go beyond the point occurring in *either* parent.

Correlation of seed weight with other characters. An attempt was made to use the figures obtained in this study to ascertain whether there is genetic correlation between the seed weight and two other characters, namely, the staple or lint length of the cotton, and the lint index, or the amount of cotton per 100 seeds. For this purpose the test proposed by Collins[1] was used, namely, the comparison between the coefficients of correlation in the F_2 and in the F_1 generation of the cross. It is assumed that if the coefficient of correlation in the F_2 generation significantly exceeds that in the F_1 generation, in the direction indicated by the relation of the parental means, coherence of characters (or genetic correlation) is indicated.[2]

The results of applying this test were as under :—

Characters	Coefficient of correlation	
1-A × Goghari cross	F_1	F_2
Seed weight and lint length	$+0{\cdot}20 \pm 0{\cdot}10$	$+0{\cdot}23 \pm 0{\cdot}04$
Seed weight and lint index	$+0{\cdot}71 \pm 0{\cdot}07$	$+0{\cdot}45 \pm 0{\cdot}03$

The relation between seed weight and lint length in the F_1 generation is slight, and is hardly altered in the F_2 generation. This indicates that there is no coherence of these characters. On the other hand, the relation between seed weight and the lint index appears strong and positive in the F_1 generation, and less strong but still positive in the F_2 generation. The correlation is, however, in the *opposite* direction to that shown in the parents. We are, therefore, driven to the conclusion that in this pair of characters also there is no genetic correlation, and that any correlation shown by the figures is purely physiological.

F. Lint index and its relation to lint length.

The lint index is the weight of lint per 100 seeds of cotton. It represents the productive capacity of the plant in lint, when considered along with the number of seeds. It has, however, not been separately examined as a special character by many workers. The more usual character studied has been the "ginning percen-

[1] Collins. Correlated characters in maize breeding. *Jour. Agri. Res.*, Vol. VI, p. 439 (1916).
[2] Kearney & Wells. *American Naturalist*, Vol. LII, p. 501 (1918).

tage ", or the proportion the weight of lint bears to the combined weight of lint and seed. This latter, though of great practical importance is, after all, a ratio, and, in fact, the ratio between two variables. It will be dealt with later, but in the meantime it may be stated that Harland[1] and Hodson[2] have found that there is a close correlation between the ginning percentage and the lint index.

Other investigations into the matter are those of Balls[3] who found that a regular distribution of lint in the seed is dominant over irregular distribution. Balls, however, makes no statement regarding the quantity of lint. Kearney (*loc. cit.*) in Holdon—Pima hybrids give figures which seem to indicate that a low lint index is at least partially dominant.

In the figures which follow, it will be noticed that the variability even of pure types is very considerable and this is what would be expected. The amount of lint on the seed, though it may partially result from the genetic constitution of the parents, yet will be obviously very largely determined by the conditions of growth and ripening. With this note, the actual figures for the parents, in this character for a series of years, with the coefficient of variation may be given.

Lint index.

——	1027 A. L. F.		1-A Cylindrical Boll		Goghari E-5	
	Mean	Coefficient of variation	Mean	Coefficient of variation	Mean	Coefficient of variation
	mg.		mg.		mg.	
1919-20	32	11·0±0·8	38	8·2±0·5	57[4]	9·7±0·6
1920-21	34	9·4±0·6	38	8·4±0·6	57	..
1921-22	33	..	38	..	59	..
1922-23	30	..	40	..	55	..
1923-24	35	..	41·5	..	60	..
1924-25	33	..	38	..	57	..
1925-26	32	9·0±0·4	36	9·5±0·4	46	13·8±0·7

[1] *Agri. News of the West Indies*, May 20th, 1916 (page 166).
[2] Hodson. Correlation of certain characters in cotton. *Arkansas Agric. Expt. Stn. Bull.* 169 (p. 15).
[3] Note on Mendelian studies in Egyptian cotton. *Jour. Agri. Sci.*, Vol. II (1908).
[4] In 1919-20—1920-21 the results of " Goghari E-5 " were obtained from the crop at Broach. The remainder were grown at Surat.

The difference between the parents with regard to this character is hence very great. The Goghari E-5 has a *very* high lint index, by far the greatest, in fact, in any known type of *Gossypium herbaceum*. The other parent, in each case, has a considerably lower value. In the first generation (F_1) of the crosses, the distribution and mean of this character in the progeny is shown below.

LINT INDEX—F_1 GENERATION.

Frequency distribution.

	28-32 mg.	32-36 mg.	36-40 mg.	40-44 mg.	44-48 mg.	48-52 mg.	52-56 mg.	56-60 mg.	60-64 mg.	Over 64 mg.	Mean mg.
1027 A. L. F.	30	43	22	5	..	..	..	..	..	..	33·9
1-A Cylindrical boll	2	23	48	21	6	..	..	..	..	..	38·2
Goghari E-5	..	..	..	1	2	16	21	22	37	8	57·3
1027 × Goghari cross	..	..	9	9	26	17	26	9	4	..	49·5
1-A × Goghari cross	..	..	7	9	11	33	31	9	..	..	49·8

The F_1 generation is therefore intermediate between the parents but with a tendency towards the parent with the higher lint index. The mean of the parental values in the 1027 × Goghari cross is 45·6 mgm., and in the 1-A × Goghari cross is 47·7 mgm.

Second Generation (F_2). The distribution of the value of the lint index in the second generation of the cross is as follows :—

LINT INDEX—F_2 GENERATION.

Frequency distribution.

	32-36 mg.	36-40 mg.	40-44 mg.	44-48 mg.	48-52 mg.	52-56 mg.	56-60 mg.	60-64 mg.	64-68 mg.	Mean mg.
1027 A. L. F.					Not recorded					32·8
1-A Cylindrical boll										38·0
Goghari E-5										58·9
1027 × Goghari cross	2	5	11	18	26	23	11	3	1	49·8
1-A × Goghari cross	1	6	8	18	23	23	11	4	1	50·3

It will be noticed that the frequency distribution in the F_2 generation is nearly symmetrical, suggesting that the character is composed of several factors. The coefficient of variation is only a little greater than in the F_1 generation, as the following figures show.

Coefficient of variation.

	F_1	F_2
1027 × Goghari cross	12·5±1·25	12·6±0·35
1-A × Goghari cross	11·0±0·79	12·4±36·0

This also suggests complexity in the character studied.

The figures for plants selected as described under previous characters in the next four generations may now be given.

Third Generation (F_3). (1) Lint index of parent plants—

	mg.
1027 × Goghari cross—	
Plant 5	42
Plant 6	46
1-A × Goghari cross—	
Plant 1	52
Plant 5	53
Plant 9	54

(2) Lint index in F_3 generation—

Frequency distribution.

	28-32 mg.	32 36 mg.	36-40 mg.	40-44 mg.	44-48 mg.	48-52 mg.	52-56 mg.	56-60 mg	60-64 mg.	Over 64 mg.	Mean mg.
1027 A. L.F.	Not recorded										30
1-A Cylindrical boll . . .											40
Goghari E-5											55
1027 × Goghari cross—											
Plant 5	..	10	14	34	21	14	5	2	..	..	43·5
1-A × Goghari cross—											
Plant 1	1	..	4	16	32	34	12	1	..	..	47·4
Plant 5	1	..	2	7	20	37	28		2	2	50·5
Plant 9	..	8	11	34	37	10	..	..	..	..	43·1

Fourth Generation (F_4). (1) Lint index of parent plants—

	mg.
1027 × Goghari cross—	
Plant 5	50
Plant 6	49
1-A × Goghari cross—	
Plant 1	51
Plant 5	43
Plant 9	45

(2) Lint index in F_4 generation—

Frequency distribution.

	28-32 mg.	32-36 mg.	36-40 mg.	40-44 mg.	44-48 mg.	48-52 mg.	52-56 mg.	56-60 mg.	60-64 mg.	64-68 mg.	68-72 mg.	Mean mg.
1027 A. L. F.	Not recorded											35
1-A Cylindrical boll												41·5
Goghari E-5												60
1027 × Goghari cross—												
Plant 6	..	3	9	*29*	33	8	5	..	..	..	..	45
1-A × Goghari cross—												
Plant 1	1	2	7	13	14	*29*	12	12	7	1	2	50
Plant 9	..	1	11	21	*35*	26	5	1	..	..	..	46

Fifth Generation (F_5). (1) Lint index of parent plants—

	mg.
1027 × Goghari cross—	
Plant 5	45
Plant 6	43·5
1-A × Goghari cross—	
Plant 1	44
Plant 5	47
Plant 9	41

(2) Lint index in F_5 generation.

Frequency distribution.

	28-32 mg.	32-36 mg.	36 40 mg.	40-44 mg.	44-48 mg.	48-52 mg.	52 56 mg.	Mean mg.
1027 A. L. F.	Not recorded							33
1-A Cylindrical boll								3[illegible]
Goghari E-5								57
1027 × Goghari cross—								
Plant 5	4	4	18	*14*	28	2	..	41
Plant 6	2	2	8	35	*47*	4	2	44
1-A × Goghari cross—								
Plant 1	2	14	*53*	27	2	2	..	39
Plant 5	1	8	13	*43*	35	..	..	42
Plant 9	..	..	7	*49*	38	3	3	44

Sixth Generation (F_6). (1) Lint index of parent plant—

	mg.
1027 × Goghari cross—	
Plant 5	37
Plant 6	44
1-A × Goghari cross—	
Plant 1	42
Plant 5	53
Plant 9	45

(2) Lint index in F_6 generation.

	20-24 mg.	24-28 mg.	28-32 mg.	32-36 mg.	36-40 mg.	40-44 mg.	44-48 mg.	48-52 mg.	52-56 mg.	56-60 mg.	Mean mg.
1027 A. L. F.	1	6	35	*49*	8	1	..	..	..	..	32
1-A Cylindrical boll	1	2	11	36	*44*	6	..	..	..	..	36
Goghari E-5	..	1	1	5	12	18	22	25	14	2	46
1027 × Goghari cross— Plant 5	4	5	8	13	24	*29*	16	1	..	..	38
Plant 6	2	3	6	7	19	*33*	27	3	..	..	40·5
1-A × Goghari cross— Plant 1	Not recorded										39
Plant 5	..	1	8	17	17	*30*	23	4	..	..	40
Plant 9	..	3	8	7	23	*47*	10	2	..	..	40

The mean values and the coefficients of variation in the last three generations will show how far, clearly distinct types have been isolated. They are as follows :—

	1923-24		1924-25		1925-26	
	Mean lint index	Coefficient of variation	Mean lint index	Coefficient of variation	Mean lint index	Coefficient of variation
	mg		mg.		mg.	
1027 A. L. F.	35	..	33	..	32	9·0±0·4
1-A Cylindrical boll . .	41·5	..	38	..	36	9·5±0·4
Goghari E-5	60	..	57	..	46	13·8±0·7
1027 × Goghari cross— Plant 5	..	..	41	10·1±0·7	38	16·5±0·5
Plant 6	45	9·5±0·6	44	8·6±0·6	41	13·8±0·6
1-A × Goghari cross— Plant 1	50	15·9±0·7	39	8·8±0·6	39	..
Plant 5	..	..	42	9·2±0·4	40	13·3±0·7
Plant 9	46	9·9±0·4	44	7·0±0·4	40	12·1±0·5

In 1925-26 the lint index decreased in all cases, and was very highly variable, as the ripening conditions were very abnormal. Judged by the coefficient of variation, however, all the types isolated have now bred true. But it is clear that al the pure segregates obtained have a value for the lint index intermediate between that of the parents. This does not mean that types do not exist with the parental values or even with extra parental values. But they have not been isolated, and the prevalence of the intermediate values shows the complexity of the inheritance of the character we are studying.

On account of the high variability in 1027 × Goghari cross, Plant 5, the parent-offspring correlation was worked out in this case. The result gave a correlation coefficient of $-0{\cdot}03 \pm 0{\cdot}10$. In other words, the segregate is pure regarding this character.

Correlation of Lint Index with Lint Length (*Staple*). The figures obtained in the F_2 and F_1 generations of these crosses have enabled us to apply the test proposed by Collins and described on (page 162) above, to see whether there is any coherence of the lint index and the lint length in the strains crossed. In this test[1] it is assumed that if the coefficient of correlation between these characters in the F_2 generation significantly exceeds that in the F_1 generation in the direction indicated by the relations of the parental means, coherence of characters is indicated. The results of applying this test in the present case are as under :—

Character	Coefficient of correlation F_1	F_2
Lint index and lint length.—		
1027 × Goghari cross	$+0{\cdot}39 \pm 0{\cdot}12$	$-0{\cdot}23 \pm 0{\cdot}04$
1-A × Goghari cross	$+0{\cdot}14 \pm 0{\cdot}10$	$-0{\cdot}36 \pm 0{\cdot}03$

These figures make it clear that there is no genetic coherence between these two characters.

G. Ginning percentage and its relation with length of staple.

The ginning percentage of any type of cotton, that is to say, the relation of the weight of lint to the whole weight of the seed cotton (*kapas*) is almost obviously a complex character being the ratio of two variables, which vary with almost if not entirely complete independence. Where the *seed* weight of the two types compared is similar, then the ginning percentages vary almost exactly in the same manner as the lint index. This is the case which occurs when the types 1027 A. L. F. and Goghari E-5 are compared and crossed. When the seed weight of the parents differ, as in the other cross under study (1-A Cylindrical Boll and Goghari E-5), the inheritance of ginning percentage is obviously an extremely complicated matter. Owing, however, to the extreme practical importance which attaches to the ginning percentage it may be worth while to follow the behaviour of this ratio when the types of cotton under study are crossed.

[1] Kearney & Wells. *American Naturalist*, Vol. 52. 1918.

The actual figures for the ginning percentage of the parents of the crosses were as follows :—

Ginning percentage.

	1027 A. L. F.		1-A Cylindrical boll		Goghari E-5	
	Mean	Coefficient of variation	Mean	Coefficient of variation	Mean	Coefficient of variation
	Per cent.		Per cent.		Per cent.	
1919-20	33·5	6·8±0·5	38·8	4·7±0·3	51·6*	2·7±0·1
1920-21	34·9	5·2±0·3	39·3	3·8±0·2	51·6*	..
1921-22	36·2	..	37·7	..	49·8	..
1922-23	33·5	..	39·0	..	48·1	..
1923-24	36·4	..	38·6	..	49·6	..
1924-25	35·8	..	36·9	..	47·6	..
1925-26	37·1	4·7±0·2	37·3	3·6±0·2	45·6	4·6±0·2

The difference between the parents is hence very great, and there is practically no overlapping. The Goghari E-5 has a *very* high ginning percentage, the highest, in fact, of any known type of *Gossypium herbaceum*. In the first generation (F_1) of the crosses, the distribution and mean value of this character in the progeny is shown below.

Ginning percentage—F_1 Generation.

Frequency distribution.

	28–30	30–32	32–34	34–36	36–38	38–40	40–42	42–44	44–46	46–48	48–50	50–52	52–54	54–56	Mean
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1027 A. L. F. . .	2	5	18	*42*	33	..	..	..	..	..	..	..	..	..	34·9
1-A Cylindrical boll .	..	..	..	4	11	*54*	27	4	..	..	..	..	..	..	39·3
Goghari E-5 . .	..	..	..	..	..	..	..	..	1	..	8	*50*	39	2	51·6
1027 × Goghari cross.					4	13	31	17	*35*	..	..	..	..	..	44·3
1-A × Goghari cross .	..	..	..	.	..	..	9	13	*45*	33	..	..	..	..	45·1

* In 1919 20, and in 1920-21, the results of Goghari E-5 were obtained from the crop at Broach.

The F_1 generation is, therefore, intermediate between the parents, but shows a very slight tendency towards the higher ginning parent. The mean of the parental values in the 1027 × Goghari cross is 43·3 per cent. and in the 1-A × Goghari cross is 45·4.

Second Generation (F_2). The distribution of the value of the ginning percentage in the second generation of the cross is as follows :—

GINNING PERCENTAGE—F_2 GENERATION.

Frequency distribution.

	36-38	38-40	40-42	42-44	44-46	46-48	48-50	50 52	Mean
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1027 A. L. F.	Not recorded								36·2
1-A Cylindrical boll									37·7
Goghari E-5									49·8
1027 × Goghari cross	2	6	8	22	27	23	10	2	44·7
1-A × Goghari cross	3	4	5	22	28	27	11	..	44·9

The frequency distribution in this generation is nearly symmetrical in both cases, suggesting that the character is composed of several factors. The variability is slightly higher than in the F_1 generation, the figures being as follows :—

	Coefficient of variation	
	F_2	F_2
1027 × Goghari cross	5·2 ± 0·5	6·7 ± 0·2
1-A × Goghari cross	4·0 ± 0·3	6·2 ± 0·3

The figures for plants selected as already described under previous characters in the next four generations may now be given.

Third Generation (F_3). (1) Ginning percentage of parent plants—

	Per cent.
1027 × Goghari cross—	
Plant 5	42·6
Plant 6	43·1
1-A × Goghari cross—	
Plant 1	42·1
Plant 5	46·0
Plant 9	40·0

(2) Ginning percentage in F_3 generation—

Frequency distribution.

	30-32	32-34	34-36	36-38	38-40	40-42	42-44	44-46	46-48	48-50	Mean
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1027 A. L. F.	Not recorded										33·5
1-A Cylindrical boll	Not recorded										39·0
Goghari E-5	Not recorded										48·1
1027 Goghari cross											
Plant 5	2	0	11	*31*	24	12	10	0	..	..	38·0
1-A × Goghari cross—											
Plant 1	..	..	..	2	13	22	*40*	18	5	..	42·5
Plant 5	..	..	1	..	1	1	12	29	*42*	14	46·1
Plant 9	..	5	3	*29*	24	21	18	..	..	..	39·2

Fourth Generation (F_4) (1) Ginning percentage of parent plants—

	Per cent.
1027 × Goghari cross—	
Plant 5	42·
Plant 6	41·[illegible]
1-A × Goghari cross—	
Plant 1	42·4
Plant 5	42·5
Plant 9	43·8

(2) Ginning percentage in F_4 generation—

Frequency distribution.

	34-36	36-38	38-40	40-42	42-44	44-46	46-48	48-50	50-52	
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1027 A. L. F.	Not recorded									36·4
1-A Cylindrical boll	Not recorded									38·6
Goghari E-5	Not recorded									49·6
1027 × Goghari cross—										
Plant 6	2	32	*34*	27	5	..	..	..	..	39·3
1-A × Goghari cross—										
Plant 1	1	9	13	17	*19*	15	14	9	3	43·1
Plant 9	..	4	18	32	*33*	11	2	..	..	41·7

Fifth Generation (F_5). (1) Ginning percentage of parent plants—

	Per cent.
1027 × Goghari cross—	
Plant 5	37·5
Plant 6	39·2
1-A × Goghari cross—	
Plant 1	40·4
Plant 5	43·4
Plant 9	41·5

(2) Ginning percentage in F_5 generation—

Frequency distribution.

	34-36	36-38	38-40	40-42	42-44	44-46	46-48	Mean
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1027 A. L. F.	Not recorded							35·8
1-A Cylindrical boll								36·9
Goghari E-5								47·6
1027 × Goghari cross—								
Plant 5	4	29	43	20	4	..	..	39·0
Plant 6	4	8	35	43	10	..	..	39·9
1-A × Goghari cross—								
Plant 1	7	41	43	9	..	..	..	38·1
Plant 5	..	2	2	19	43	34	..	43·1
Plant 9	..	..	1	20	60	18	1	42·9

Sixth Generation (F_6). (1) Ginning percentage of parent plants—

	Per cent.
1027 × Goghari cross—	
Plant 5	38·5
Plant 6	40·5
1-A × Goghari cross—	
Plant 1	41·1
Plant 5	44·3
Plant 9	42·9

(2) Ginning percentage in F_6 generation—

	32-34	34-36	36-38	38-40	40-42	42-44	44-46	46-48	48-50	Mean
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
1027 A. L. F. . .	5	21	*43*	26	5	..	..	..	..	37·1
1-A Cylindrical boll .	2	15	*50*	32	1	..	..	..	..	37·3
Goghari E-5 . .	...	..	..	3	2	12	*39*	32	12	45·6
1027 × Goghari cross—										
Plant 5 . .	..	5	14	29	*35*	17	..	..	..	39·9
Plant 6 . .	..	1	7	20	*46*	23	3	..	..	40·9
1-A G ghari cross—										
Plant 5 . .	..	..	..	2	17	*35*	30	15	1	43·9
Plant 9 . .	..	..	1	4	21	*38*	32	4	..	43·1

The mean values and the coefficients of variation in the last three generations will show how far clearly distinct types have been isolated. They are as follows :—

	1923-24		1924-25		1925-26	
	Mean Ginning percentage	Coefficient of variation	Mean ginning percentage	Coefficient of variation	Mean ginning percentage	Coefficient of variation
	Per cent.		Per cent.		Per cent.	
1027 A. L. F.	36·4	..	35·8	..	37·1	4·7 ± 0·2
1-A Cylindrical boll . . .	38·6	..	36·9	..	37·3	3·6 ± 0·2
Goghari E-5	49·6	..	47·6	..	45·6	4·6 ± 0·2
1027 × Goghari cross—						
Plant 5	..	..	39·0	4·3 ± 0·3	39·9	5·5 ± 0·2
Plant 6	39·3	4·7 ± 0·3	39·9	4·5 ± 0·3	40·9	4·7 ± 0·2
1-A × Goghari cross—						
Plant 1	43·1	8·7 ± 0·4	38·1	4·2 ± 0·3	39·2	..
Plant 5	..	..	43·0	3·9 ± 0·2	43·9	4·8 ± 0·2
Plant 9	41·7	5·3 ± 0·2	42·9	3·7 ± 0·2	43·1	4·3 ± 0·2

It will first of all be noticed that all values in the crosses are intermediate between the parents, and this is the case although the types isolated seem, as judged by the coefficient of variation, to be pure in this character. One type of each cross approaches the value of the lower ginning parent; the others, while clearly intermediate, are more nearly approaching the higher ginning parent. Among the type isolated there is no sign of any which goes beyond either parent.

Correlation of ginning percentage with other characters.

An attempt was made to use the figures obtained in this study to ascertain whether there is genetic correlation, or coherence of characters, between the ginning percentage and the staple of the lint. There is a very widespread impression among cotton growers that a high ginning percentage is almost, if not entirely, inconsistent with a long staple cotton. There has, hitherto, been no positive evidence in favour of this view. In fact, what evidence exists, seems to show that the two characters vary independently. The application of the test proposed by Collins (p. 162) in the present case may give some information on the point.

If we compare the correlation between the two characters concerned—ginning percentage and staple—in the F_1 and F_2 generations, genetic correlation would be shown if there is greater intensity of correlation in the F_2 generation, in the same direction as occurs in the parents. The following are the figures actually obtained.

Coefficient of correlation between ginning percentage and staple.

	F_1	F_2
1027 × Goghari cross	+0·31 ± 0·1	—0·35 ± 0·03
1—A × Goghari cross	—0·39 ± 0·1	—0·60 ± 0·03

So far as the 1027 × Goghari cross is concerned, there is no evidence of any coherence between these characters. In the 1-A × Goghari cross the result is not so clear, and there is marked intensification in the correlation in the F_2 generation in the same direction as occurs with the parents. The result tends to show that in certain cottons only there is reason to suspect some coherence between the two characters dealt with. The matter, however, requires much more investigation and the application of the test in many other cases. If such further investigation confirms the result just given, it may indicate a reason for the apparent difficulty in combining maximum ginning percentage with the highest staple.

III. General conclusions.

The object of the work reported in the present memoir was deliberately and definitely the production of a type of cotton for the Surat and Broach Districts, which while retaining the staple and quality of the present fibre should, at the same time, have a higher ginning outturn. This has been successfully accomplished in the case of a cotton suitable for Broach and this is now being multiplied for distribution on a large scale. A similar result appears also to have been achieved in connection with cottons suitable for Surat, though it is not quite certain whether the spinning value of the typical high class Surat cotton (1027 A. L. F.) has been retained.

Incidental to the above practical object, the data collected have been employed to study seven characters of the cotton plants used as parents of two crosses between pure types of Broach-*deshi* (1027 A. L. F. and 1-A Cylindrical boll) and of Goghari (E-5) Cottons,—all being strains of *Gossypeum herbaceum*, and also the same characters in six generations of the resulting crosses. The main objects of the study were two, as follows :—

(*a*) To determine whether the characters studied are simple Mendelian characters which can be transferred without change from plant to plant, or are complexes of a number of factors which, while normally inherited together, may be separated in the course of inheritance.

(*b*) To ascertain whether the several characters studied are genetically correlated, that is to say, whether there is coherence of these characters during inheritance.

The results of the enquiry dealing as it does with the following characters may now be given :—

(*a*) *Node in the Stem from which the first Sympodium arises.* This character, when fixed definitely in the fifth and sixth generation of the cross, conforms to one or other of the parents, except in one case. In this case, the node is higher on the stem than that of either of the parents. This indicates that we are dealing with a complex character, of which the elements cohere closely. But it shows the possibility of being able by crossing to obtain a form of plant different from the parents and suited to particular conditions.

(*b*) *Diameter of the Bolls.* A large boll is an advantage, and hence the interest of the present study in this respect. Out of five types followed out to the sixth generation of the cross, two conform to one or other of the parents. Two are intermediate between them, out of which the purity of one is doubtful. The fifth, however, has a larger boll than either of the parents from which it is produced, and yet it definitely breeds true. This indicates that the maximum diameter of the bolls is a complex character. But it shows the possibility of being able by crossing to obtain a larger boll than that of either parent,—a result achieved in the present case.

(*c*) *Shape of the Boll.* The shape of the boll, as judged by the boll index, has proved itself again a complex character which *may*, from the evidence, be composed of two factors. All the plants obtained, when the types were found to be fixed (as judged by means of the coefficient of variation), conformed, however, in this character to one or other of the parental types, and thus indicated the very close linkage of the factors which determine the shape of the boll.

(*d*) *Length of Staple.* When stable and fixed types of plant in respect to lint length are obtained in the fifth and sixth generation of the cross, it was found that out of five types obtained three conformed almost exactly to the type of one of the parents, one was intermediate between the parents, and one has a staple distinctly longer than the longer parent. This indicates that we have to deal with a complex character, and indicates the possibility of obtaining by crossing types of longer staple than any of those which are now grown, and which could be used as parents.

(*e*) *Weight of Seed.* The weight of the seed proves to be a complex character, with at least partial dominance in the direction of heavier seed weight. There are indications that it is possible to obtain types with seed weight lower than either of the parents, a fact which opens up new possibilities in cotton breeding. There appears to be no genetic correlation in the cottons examined between the seed weight and either the lint length or the lint index.

(*f*) *Lint index* or the weight of lint per one hundred seeds. In this matter all pure types of the cross isolated have values intermediate between those of the parents. This does not mean that strains do not exist with the parental values or even with values beyond these latter, but it does indicate the complexity of the character. There appears to be no genetic correlation between the lint index and the lint length.

(*g*) *Ginning Percentage.* This character, which is really only a ratio between the lint index and the total weight of the seed and lint together is only studied because of its commercial importance. As would be expected from the results with the lint index, the values obtained in the cross are all intermediate between the parents. There seems some evidence of a partial coherence between this character and the lint length in a negative direction, in certain cases only.

MGIPC—M—IV-2-78—15-6-27—650.

CONTENTS

THE INDIGENOUS COTTON TYPES OF BURMA.

BY

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(Received for publication on 1st December, 1926.)

Introduction.

A survey of the principal cotton types of Burma was commenced in 1921.

The cultivated cottons of the province are comparatively well known and the component types have been referred to definite sub-varieties by the different authors on Indian cottons.

Thus Gammie [1] separates the *Wagale* crop of Upper Burma into three sub-varieties of *G. neglectum*, Tod. and considers that *G. obtusifolium*, Roxb. var. nov. *Nanking*, is represented by both *Wagyi* and *Wagale* types. In his tentative classification of Indian Cottons [2] he refers to the cottons of the Shan States and Chin Hills as the possible source of two further distinct types making six in all.

Watt [3] does not distinguish clearly between the cultivated forms.

He ascribes specimens of *Wagyi* and *Wagale* to *G. Nanking*, Mayen, and states that *G. arboreum*, var. *neglecta*—the *G. neglectum* of Todaro—is cultivated in Burma. He also quotes Dr. Buchanan Hamilton to the effect that a red-flowered field cotton, inferred by Watt to be *G. arboreum* var. *sanguinea*, is known to the Burmans as "wa been." Wa been is obviously a mispronunciation of "wa bin" which simply means "cotton plant" and it may be stated here that I have met with no red-flowered cottons in the course of the present investigation. Insomuch also that *Wagyi* and *Wagale* are dissimilar types, it seems evident that Watt and Gammie were misguided in ascribing specimens of both these cottons to the same sub-variety. Owing to admixture of seed at the ginneries, specimens of *Wagyi* sometimes occur in the *Wagale* crop and it is only reasonable to assume that specimens are occasionally sent out wrongly labelled.

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[1] Gammie, G. A. The Indian Cottons. *Mem. Dept. Agri. India, Bot. Ser.*, Vol II, No. 2.
[2] Gammie, G. A. Classification of Indian Cottons (tentative), 1903.
[3] Watt, Sir George. The Wild & Cultivated Cotton Plants of the World, 1907.

Burkill [1] seems to have recognized six types as belonging to Burma, for he says "I have lately received two capsules from Padaung near Prome of what may be a seventh cotton—a khaki cotton grown on Taungyas and perhaps being that spoken of in the *Journal of the Agri-Horticultural Society of India.*[2]

But outside the limits of the two main areas of cultivation and ranging from the Assam border through the Chin hills and Pakokku hill tracts on the west, and from China through the Northern and Southern Shan States on the east, occur sparsely cultivated a series of cottons about which little has hitherto been known

It was considered that a comprehensive knowledge of all the existing types would, apart from their intrinsic interest, provide a suitable basis on which to commence the work of cotton improvement.

A collection of seed samples was, therefore, obtained from the various localities where cotton occurred. These were grown at Mahlaing for preliminary observation. In the case of the varieties under general cultivation, the isolation of fixed types presented no difficulty. From some of the hill tracts, however, the crop showed great diversity and it became obvious that the bulk of the forms were of hybrid origin. It became necessary, therefore, to select the predominant types and to inbreed in order to obtain pure lines.

To eliminate the hybrid tendencies it became necessary to continue the cultures from self-fertilised seed for several years at the Mahlaing Experimental Station, where the cultural and climatic conditions are typical of the *Wagale* tract. It has been observed by other writers that morphological characters in cotton undergo modification when transfer takes place from one habitat to another. The descriptions given in the following pages were taken from pure cultures in the year 1925, but it may be observed that, apart from an increase in the general vigour of the plants, the descriptions conform nearly to those taken for certain of the types in their natural habitat. To indicate to what an extent this is true, I have against types XII and XV given the photographs of herbarium specimens collected in the Chin hills in the year 1920.

It is doubtful, of course, if any of the cultivated races of cotton in Burma can be regarded as truly indigenous. So far as I am aware, no wild species has been recorded from Burma and it is extremely unlikely that the cultivated forms have had a separate origin of their own. They can, in fact, all be more or less definitely assigned to one or other of the well-known Indian species and it may be reasonably assumed that they have arisen from the same common stock as the latter. At the same time there are indications that the cottons of Central Asia have entered largely into their composition and influenced their development to perhaps a greater extent than has been the case in the majority of Indian cottons.

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[1] Burkill. Report on Cotton in Burma, 1904.
[2] *Jour. Agri-Horticultural Society of India,* Vol. XII, 1862, page 176.

Description of types.

Type I.

A late maturing pyramidal shrub about 7′ in height. Stem robust, reddish brown, stellately tomentose and pilose with long hairs; internodes short; branches approximate, monopodial, ascending acutely. Main axis prolonged, with sympodial axes shortening successively towards the apex.

Leaves rather small, palmatipartite, unevenly cordate, light green, hirsute beneath, ultimately coriaceous, margins often sinuate in the larger leaves: leaf-glands 3. Lobes 5 to 7, broadly ovate, subacute; sinuses of variable width, with occasional accessory lobes.

Bracteoles small, ovate-cordate, acute, serrate with 5 teeth in the upper margin.

Flowers yellow, solitary on short erect peduncles from the secondary and tertiary sympodial axes.

Bolls medium-sized, ovoid, rostrate, obscurely gland-dotted, 3-4-locular.

Seeds 8 to 10, rostrate; fuzz greenish grey.

Lint white, copious, of medium length, but somewhat coarse.

Type II.

This type is like type I, but with buff-coloured lint.

Type I is the *Waggi* of Lower Burma where it is cultivated extensively in the districts of Thayetmyo and Prome. It has been assigned by Watt to *G. Nanking*, Mayen and by Gammie to *G. obtusifolium*, Roxb. var. nov. *Nanking*.

The khaki linted form described under type II occurs in the cultivated crop to only a small extent and is separated out at the ginneries as a recognized impurity. It is probably this type which was referred to by Burkill as possibly a seventh form from Burma, though it is certainly not the cotton spoken of in the *Journal of the Agri-Horticultural Society of India* of 1862.

Type III.

A medium-maturing monopodial form of similar habit to type I.

Stem and *young leaves* densely pilose.

Leaves large, palmatipartite, subcordate, dark green, eglandular. Lobes 5, ovate oblong, acuminate, somewhat constricted at their bases; sinuses narrow, accessory lobes rare.

Bracteoles medium-sized, ovate, subcordate, the upper margin laciniate.

Flowers white, solitary on elongate nodding peduncles.

Bolls fairly large. ovoid-oblong, acuminate, 3-4-locular.

Seeds 9 to 11 ; fuzz greyish white.

Lint white, of medium length, but rather coarse.

Type III is a monopodial form received from Mauk Mai in the Southern Shan States. It appears to be closely related to the cottons described in Gammie's group *G. intermedium*, Tod. and is most probably identical with one of the forms received by Leake [1] from Siam. Of all the types described, this is the only form in which leafglands are absent.

Type IV.

A tall but early maturing shrub with the few lower monopodial branches long and ascending and the upper sympodial branches short and spreading.

Stem and *Petioles* distinctly gland-dotted, the stem ultimately turning to reddish brown; herbaceous parts clothed with white caducous hairs.

Leaves large, palmatipartite, cordate, dark green, coarse-looking ; leaf-glands 1 to 3. Lobes 5 to 7, lanceolate, undulate, usually with accessory lobes in the somewhat wide sinuses.

Bracteoles large, ovate, acute, auriculate at the cordate base, prominently serrate in the upper margin.

Flowers yellow, solitary on erect peduncles from the short lateral axes.

Bolls fairly large, ovoid, acuminate, conspicuously gland-dotted, 3-4-locular.

Seeds 8 to 10 ; fuzz greyish green.

Lint white, copious, but short and coarse.

Type V.

This type differs from type IV in its white flowers, larger bracteoles and heavier outturn of lint.

Type VI.

This type resembles type IV in all characters except the buff-coloured lint.

Types IV to VI make up the *Wagale* crop and constitute the bulk of the export staple.

Gammie has placed these types as follows :—

Type IV. *G. neglectum*, Tod. var. nov. *vera*, sub-var. nov. *burmanica*.

Type V. *G. neglectum*, Tod var. nov. *rosea*.

Type VI. *G. neglectum*, Tod. var. nov. *vera*, sub-var. nov. *Kokatia*.

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[1] Leake, H. M.; and Ram Prasad. Observations on certain Extra-Indian Asiatic Cottons. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. IV, No. 5.

All three types are grown in mixture with type IV predominating. Type VI occurs in very small quantities and must be regarded as an impurity except where it finds local preference for the making of a durable cloth known as "Pinni."

The types occur widely distributed through Upper Burma, but it is in the districts of Meiktila, Myingyan, Sagaing and the Lower Chindwin that they attain their maximum importance.

Type VII.

A plant of distinctly cylindrical shape, 3′ to 4′ in height, with few or no monopodial branches. The sympodial branches are of uniform length, short and spreading, with a tendency to droop.

Stems pilose when young, green turning to reddish brown.

Leaves of medium size, palmatipartite to palmatifid, subcordate or obtuse at the base, often undulate in the margin, soft, hirsute, dark green : leaf-glands 1, rarely 3. Lobes usually 5, ovate, acuminate, somewhat constricted at their bases, with occasional accessory lobes.

Bracteoles $\frac{2}{3}$ the length of the corolla, ovate-triangular, with inflexed margins, purple tinged, serrate in the upper margin by 6 or 7 teeth, base cordate.

Flowers white, borne 3 or 4 to each secondary axes on short peduncles.

Bolls medium-sized, sub-angular, attenuate to the apex, 3-4-locular.

Seeds 8 to 10 ; fuzz darkish grey.

Lint white, long, exceedingly soft and fine.

Type VIII.

This type differs from type VII in its greater tendency to develop monopodial branches, in its 6 to 9 seeds being covered with a greyish brown fuzz, and in its pale buff-coloured lint.

Type IX.

A taller and more diffusely branched plant than type VII, with often one or more elongate monopodial branches, median branches fairly long and spreading, with a slight tendency to droop.

Leaves of medium size, palmatipartite, subcordate, thin in texture, subglabrous, dark green : leaf-glands 1 to 3. Lobes usually 5, oblong, not constricted at the base and without accessory basal lobes.

Bracteoles large, green, almost as long as the corolla, ovate-triangular, subcordate, the upper margin serrate by 5 teeth.

Flowers yellow, 3 to 6 from the secondary axes, borne singly on elongate suberect peduncles.

Bolls ovoid, acute, 3-locular.
Seeds 8 to 10 ; fuzz greenish grey.
Lint of medium length, soft and fine.

Type X.

A plant similar to type IX, but with longer internodes. The median branches arise at a sharper angle with the stem and droop at the ends.

Leaves large, palmatifid, cordate, coriaceous, sub-corrugate : leaf-glands variable in number, the leaves on the main stem with 3 and those on the secondary branches with 1 only. Lobes 5, broadly ovate, acute.
Bracteoles small, about $\frac{2}{3}$ as long as the mature boll to which they are adnate, broadly ovate, flushed with purple.
Flowers yellow, 4 or 5 from the secondary axes, borne on very short pendent peduncles.
Bolls medium-sized, short ovoid, acute, 3-4-locular.
Seeds 8 to 10 ; fuzz greyish brown.
Lint pale buff of good length, but very scanty.

Type XI.

This type is characterised by its rigid appearance. The median branches are longer than those of type X, more erect, and without the tendency to droop.

Leaves very large, of lighter colour and softer texture than those of type X, palmatipartite, cordate : leaf-glands 1 to 3. Lobes usually 5 to 7, large, undulate, the median produced and with accessory basal lobes.
Bracteoles large, broadly ovate, laciniate by 5 narrow lobes, tinged with purple.
Flowers as in type X.
Bolls ovoid, acute, 3-locular.
Seeds 9 to 10 ; fuzz greenish grey.
Lint white of good length and quality.

Types VII to XI are a representative series from the Northern and Southern Shan States. All the forms are of typical sympodial habit and early maturity, producing soft fine staple up to an inch in length and of excellent quality. The crop is grown mainly for local consumption, though consignments are often carried over considerable distances to collecting centres from which the *kapas* is despatched to the Burma ginneries.

The types all bear close resemblance to *G. indicum*, Gammie and to *G. Nanking*, Mayen which Watt considers to be the great cotton of Central and Eastern Asia.

TYPE XII.

A small and very early-maturing shrub 3′ to 4′ in height. Branches mostly sympodial with a few short, spreading monopodia. Stem light brown turning to grey. Median branches comparatively long, delicately slender and drooping with elongate internodes giving the plant a decidedly graceful appearance. The median branches are usually longer than the basal.

Leaves medium to small, palmatifid, subcordate, thin in texture, light green: leaf-glands 1, rarely 2 or 3 on the lower leaves. Lobes 3 to 5, triangular, acute or obtuse, with wide unfolded sinuses.

Bracteoles ovate-triangular, cordate, serrate in the upper margin by 5 teeth, very small, adnate to the boll, purplish.

Flowers yellow, 5 to 7 from the elongate secondary axes, borne on short nodding peduncles.

Bolls small, elongate, acute, 3-4-locular.

Seeds 6 to 8; fuzz grey.

Lint white, fairly long and fine, but sparse.

TYPE XIII.

This type differs from type XII in its deep buff-coloured lint.

TYPE XIV.

A plant of similar habit to type XII, but more robust and with the median branches straighter and more rigid.

Bracteoles medium-sized, serrate by 3 or 4 teeth, otherwise as in type XII.

Flowers dead white, with bright crimson blotches at the bases of the petals.

Bolls as in type XII.

Seeds small, 6 to 8; fuzz dark grey.

Lint white, long, soft, fine, but exceedingly sparse with a ginning outturn of only 21·24 per cent.

TYPE XV.

A plant 5′ to 6′ in height, of typically sympodial habit, with a few erect monopodia and very short spreading median branches.

Leaves dark green, palmatisect, subcoriaceous: leaf-glands 1 to 3. Lobes 5 to 7, oblong-lanceolate, the lower-most pair divaricate from the subcordate base.

Bracteoles large, very broadly ovate, cordate, laciniate by 5 or 6 narrow lobes.

Flowers yellow, 3 or 4 on the short median branches.

Bolls large, sub-spherical, acute, 3-4-locular.
Seeds 6 to 8; fuzz greyish white.
Lint white, soft, fine, of good length.

Type XVI.

A shorter and more delicate plant than type XV, with slender drooping branches. It differs from type XV also in having smaller and more triangular bracteoles and white flowers.

Type XVII.

This type is similar to type XV. The flowers are yellow and the lint a pale buff in colour, soft, of medium length and scanty.

Type XVIII.

A large plant of pyramidal shape, with numerous monopodial branches arising from the base at an angle of about 45 degrees. Median branches short and spreading.

Leaves as in type XV.
Bracteoles of medium size, broadly ovate, cordate, laciniate in the upper margin, purplish.
Flowers yellow, 3 to 5 on the secondary branches and 1 or 2 on the tertiary, borne on erect peduncles.
Bolls fairly large, ovoid-oblong, acute, 3-4-locular.
Seeds 8 or 9; fuzz greyish white.
Lint white, fairly long and fine, but sparse.

Types XII to XVIII occur sparsely cultivated throughout the Chin hills and Pakokku hill tracts where the crop is confined to small Taungya plots on the steep hill-sides. The crop is a very mixed one. A wide range of forms give a clear indication of hybrid origin and on certain plots it was almost impossible to separate out predominant types. From a critical study of a wide series of samples it has, however, been possible to isolate two main groups.

Types XII to XIV are a characteristic group with close affinities to *G. indicum*, Gammie. The leaves are small and true to type; the cotton exceedingly scanty but fine and of good quality.

Types XV to XVIII in the shape of their leaves and large bracteoles have feature in common with *G. arboreum* var. *assamica*, Watt and *G. cernuum*, Tod. They, however, differ from these in having scanty cotton of soft fine quality.

Type XIX.

A small plant, 3′ to 4′ in height, with few or no monopodial branches. Median branches short and suberect.

Leaves medium-sized, light coloured, palmatipartite. Lobes usually 5 to 7, narrow, radiate.

Bracteoles medium-sized, broadly ovate, subcordate, serrate in the upper margin.

Flowers white, 3 or 4 borne on short pendent peduncles from the secondary branches.

Bolls large, broadly ovoid, obtuse, 3-4-locular.

Seeds 10 to 20 ; fuzz greyish.

Lint white, very copious, but short and very coarse.

Type XX.

This type is similar to type XIX, but the lint is buff-coloured.

Types XIX and XX were obtained from the Arakan hill tracts. They correspond in all respects to the cottons described by Gammie under *G. cernuum*, Tod. and have probably been introduced into Arakan from the hill tracts of Assam. It is undoubtedly these cottons which are referred to in the *Journal of the Agri-Horticultural Society of India*, Vol. XII, 1862, and described as native cottons with harsh strong but very short staple.

Seed and lint characters.

Certain determinations for seed and lint characters are given in the Appendix. The main object in view in recording this data is to provide a set of figures which will give the plant breeder an indication of the respective type values. The determinations were made from one hundred fully matured bolls selected at random from each line culture and are intended to do no more than convey an idea of mean values.

The mean weight of kapas per boll was obtained on the weight of one hundred bolls.

The number of seeds per boll and number of seeds per loculi were determined on account of ten bolls.

The weight of lint per seed and seed weight were determined on weighments of one hundred seeds before and after ginning. The weighments were carried out on successive days during the dry weather so that, as Hilson [1] has shown, the error due to fluctuations in humidity may be ignored.

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[1] Hilson, G. R. Methods of Examination of Certain Characters in Cotton. *Bull.* No. 138, *Agri. Res. Inst., Pusa,* 1923.

Length of lint was calculated on measurements taken along the radius from the combed halos of five seeds selected one each from five different locks, a method used by Balls[1] and which, for all practical purposes, has been shown by Hilson [2] to give a significant result.

Ginning percentage expresses the number of units of lint in a hundred units of *kapas*. The determinations were made from the *kapas* remaining after the other data has been recorded and it should be noted there is sometimes a slight variation between this figure and that obtained from a calculation based on mean weight of lint per seed and mean seed weight.

In conclusion, it may be stated that the above types are being maintained in pure cultures and the best of them are being incorporated in breeding experiments to evolve a better type of cotton for the *Wagale* tract of Burma.

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[1] Balls, W. L. The Development and Properties of Raw Cotton, 1915.
[2] *loc. cit.*

APPENDIX.

Seed and lint characters.

Type	Mean weight of *kapas* per boll	Mean number of seed per boll	Mean number of seed per lock	Mean weight of lint per seed	Mean weight of seed	Mean length of lint	Ginning per cent.	Colour of lint
	Grm.			Mg.	Mg.	Mm.		
1	2·99	26·4	8·51	52	73	23	41·25	White.
2	2·49	26·7	8·9	41	59	20	40·32	Buff.
3	2·34	25·1	8·36	32	59	20	34·53	White.
4	1·70	25·0	8·06	21	44	18	32·38	White.
5	2·40	25·4	8·19	34	60	17	36·37	White.
6	1·88	25·4	8·19	24	44	17	34·38	Buff.
7	1·82	28·8	8·23	17	45	25	27·41	White.
8	1·67	22·5	7·5	19	53	24	26·56	Pale buff.
9	2·26	26·3	8·0	24	59	20	28·13	White.
10	1·52	24·9	8·3	13	46	23	22·45	Pale buff.
11	1·66	28·1	9·06	20	52	23	27·37	White.
12	1 34	23·8	7·68	12	43	23	21·87	White.
13	1·68	26·8	8·93	15	46	25	24·48	Deep buff.
14	1·11	23·0	7·42	12	46	24	20·60	White.
15	2·02	22·7	7·32	27	59	23	31·42	White.
16	1·19	28·0	8·75	13	40	21	25·00	White.
17	1·16	24·2	8·06	21	45	20	31·94	Buff.
18	1·87	24·1	8·03	16	47	24	25·73	White.
19	2·68	31·3	10·43	36	49	15	43·49	White.
20	3·46	31·5	10·51	52	67	15	43·08	Buff.

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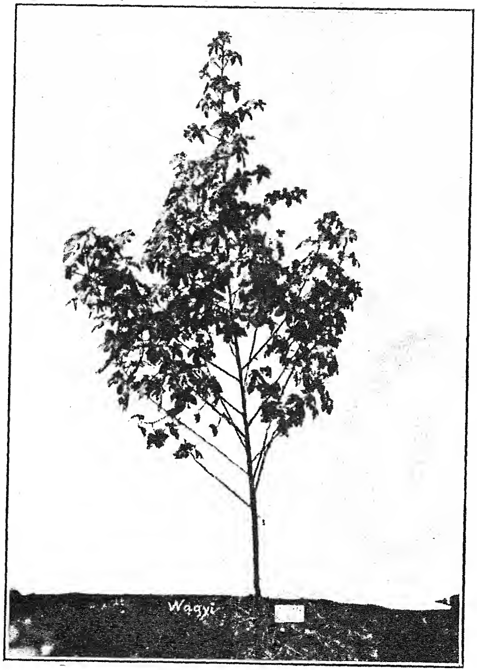
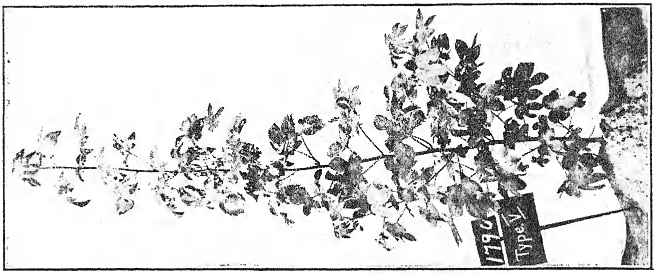


Type I.

Type III.

PLATE II.

Type VII.



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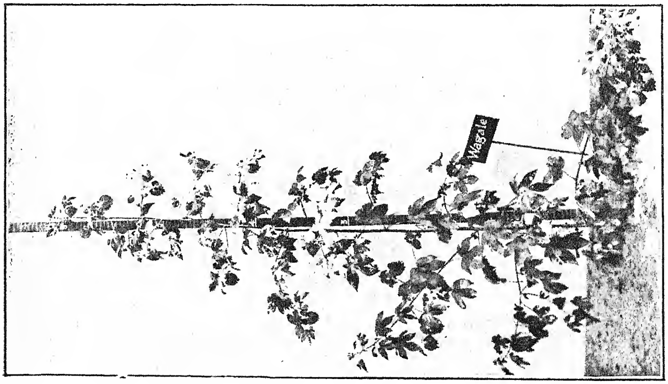
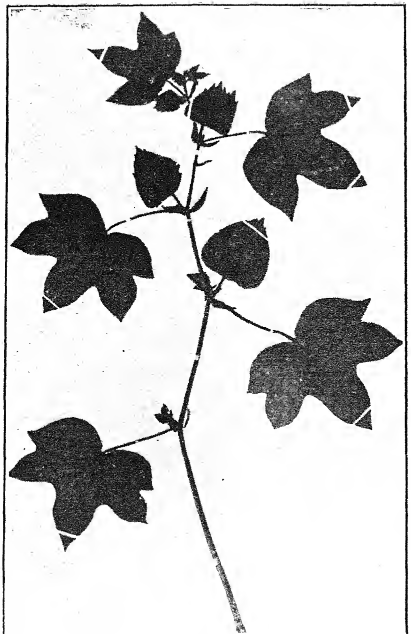


Type IV.

Type IX.

Type X.

Type XI.



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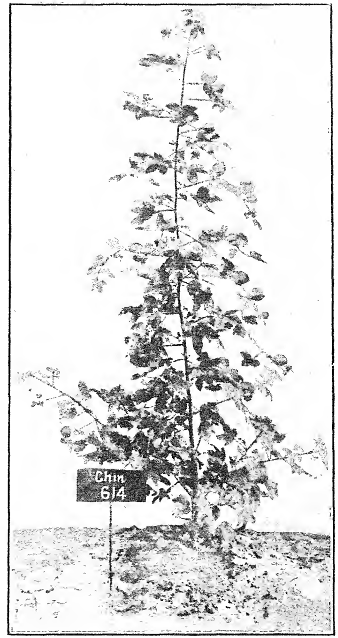
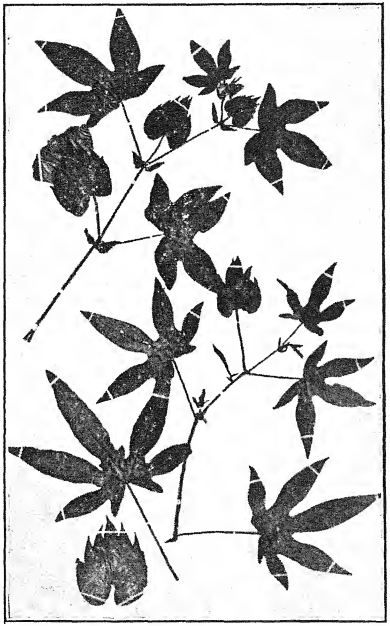


Type XII.

Type XIX.

Type XV.



Type XV.

Type XVIII.

A STUDY OF *FUSARIA* COMMON TO COTTON PLANTS AND COTTON SOILS IN THE CENTRAL PROVINCES*.

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(Received for publication on 18th December 1926.)

Introduction.

For many years past it has been known that some varieties of cotton in certain fields become badly infected with " wilt ", whereas the same varieties in other fields remain healthy. For example, *Roseum* has been found to be so susceptible to this disease that its cultivation in these " wilted " fields is not economical. From wilted cotton plants *Fusaria* spp., have been isolated, especially one particular species more often than others. Investigations were therefore undertaken, first, to compare the soil *Fusaria* of " wilted " and " non-wilted " cotton fields with the *Fusaria* isolated from wilted cotton plants, and secondly, to study their parasitism.

For these investigations, isolations of *Fusaria* have been made from time to time during the years 1923 to 1925, (A) from samples of soils taken in Nagpur from (1) fields in which *Roseum* and other susceptible varieties of cotton have been for several years known to be badly wilted, (2) from fields in which the same varieties of cotton have remained healthy, (3) from a field, which we shall call field A, in which " wilt " was of recent occurrence and (B) from wilted cotton plants received from various parts of the Central Provinces and Berar.

Method of isolating Fusaria from soil.

Samples of the different soils were taken by means of a sterilized soil borer. By the use of this instrument a cylindrical lump of earth, one inch in diameter and eight inches deep, was obtained. Each sample of soil was thoroughly shaken up with a litre of sterilized distilled water in sterilized glass vessels. The mixture was allowed to stand overnight. The following day the supernatant liquid was removed by a sterile pippette and mixed with sterilized resin agar, previously melted

* The author wishes to express his acknowledgments to the Indian Central Cotton Committee for the financial help given by them for the investigation of this problem.

and cooled to 40°C., in the proportion of 1 c.c. of the supernatant liquid to 50 c.c. of the melted agar medium. This inoculated nutrient medium was then placed in sterile Petri dishes. Fungus colonies were visible in about three days' time. This medium had the advantage of checking completely bacterial growth; but the growth of fungi was very poor and after several trials it was found that the addition of ½ per cent. Lemco and 2 per cent. glucose gave a much better growth. Therefore, this modified resin agar * was used in later isolations. *Fusarium* colonies were very often overrun by quickly growing fungi, like *Mucor*, *Penicillium*, *Aspergillus*, etc.

Fusaria from cotton soils and from wilted cotton plants.

From the cotton soils seven distinct strains of *Fusaria* have been repeatedly isolated. Of these, three strains were isolated from each of the three kinds of fields mentioned above and also from wilted cotton plants. One strain was isolated only from a "non-wilted" field, another strain only from "wilted" fields and the remaining two strains were obtained only from the field A.

Specimens of diseased cotton plants were obtained from several places in the Central Provinces and Berar and from Ujjain in Central India. From these specimens four different strains of *Fusaria* in addition to a species of *Rhizoctonia* have been isolated.

Of these four strains of *Fusaria* from wilted cotton plants, one strain is entirely different from the seven distinct strains so far isolated from the soil. The other three strains are identical with three of the strains from the soil.

Mr. G. S. Kulkarni from Dharwar very kindly sent a culture of the *Fusarium* on cotton, isolated by him from diseased cotton plants.

Every *Fusarium* that was obtained from wilted cotton plants or soil was cultivated on a variety of nutrient media. By the end of 1925, altogether 40 *Fusaria* were isolated from different cotton fields in Nagpur. Innumerable cultures were also made from wilted cotton plants from different cotton tracts. From the study of these *Fusaria* on various nutrient media it was finally established that there were really only eight distinct strains.

The nutrient media used were glucose agar, starch glucose agar, saccharose agar, potato extract agar, rice-meal agar, liquid potato extract, cooked potatoes, cooked wheat, cooked gram, and cooked rice. On cooked rice, the growth was very luxuriant; most of the *Fusaria* developed beautiful bright colours and the fungus remained viable for several months.

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* This medium was prepared as follows :—

60 grams of resin were heated at about 80° C. in one litre of tap water for one hour and filtered. The filtered portion was then made up to one litre and 25 grams of agar agar, 4 grams of Lemco and 20 grams of glucose were dissolved in it. The medium was then autoclaved at 15 lbs. pressure for 20 minutes.

For the purpose of comparison of growth, mode of development, colour production, spore formation, etc., on these media, each of the *Fusaria* was subcultured on the same day and on the same medium in three or four flasks or tubes or Petri dishes. The quantity and quality of the medium were the same in every case and the flasks or tubes or Petri dishes used were of the same size. For agar media tubes or Petri dishes were used and for liquid media and media such as cooked rice, etc., Erlenmeyer flasks of 250 c.c. capacity were used.

A complete record of the changes in colour and of growth of each of these cultures was kept for several months and observations were recorded every third or fourth day. All colour determinations have been made with the help of the following publication :—

" Répertoire de Couleurs des Fleurs des Feuillages et des Fruits " published by La Société Française des Chrysanthémistes et René Oberthür, (1905).

The cultures were studied both microscopically and macroscopically. Several spore measurements were taken from each culture and the average length and breadth of 1—, 2—, 3—, or multiseptate spores were ascertained. The form, nature of septation, abundance of microconidia, nature of the sporodochium, hypha measurements, and shape, size and presence or absence of chlamydospores were also studied.

Description of various strains.

It is not necessary for the purpose of this paper to describe critically all the soil *Fusaria* so far studied. We shall here confine ourselves to the description only of the four strains of *Fusaria* that have been isolated from wilted cotton plants. As already noted, three of these have also been found in cotton soils and the fourth *Fusarium* has so far not been obtained from the soil, but presumably it must be present.

Strain A.

This strain was isolated from most of the wilted cotton plants obtained from Nagpur, Wardha, Akola, Murtizapur, Drug, Borgaon, Dharwar and Ujjain. It was also isolated from " wilted " and " non-wilted " cotton fields.

This fungus shows variations in colour when it is grown for several generations on cooked rice. In the first two or three generations it developes a violet colour, but in later generations the colour is at first violet, which soon changes to violet purple and finally becomes scarlet red. (Plate II, figs. 1 and 2).

On cooked rice it has usually an aerial growth, which is sometimes cauliflower like. On rice-meal agar the colour is at first pale light lilac, which changes to Bishop's violet and finally becomes bright violet purple. On this agar medium the growth is concentric and at first slimy, but later the central portion becomes powdery, though the concentric development persists.

Microspores vary in shape, are hyaline in colour and measure 9—18μ×3—4μ, average 12×3·4μ. Macrospores are falcate in shape, one end being slightly incurved, hyaline in colour and are one to five septate; usually three septate. (Pl. III, Fig. 1) Macrospore measurements on glucose agar from a 10 days' old culture are as follows :—

1—septate, 15-25μ×3-4·5μ, average 20×3·5μ ;

2—septate, 20-30μ×3·5-5μ, average 25·5×4μ ;

3—septate, 25-50μ×4-6μ, average 34×4·5μ ;

4-5—septate, 38-50μ×5-6μ, average 43×5μ.

Hyphae are 2-6μ broad. Chlamydospores are generally present in old cultures. They are round or elliptical, intercalar or terminal and measure 5-10μ×6-10μ. (Plate III, fig. 4). In old cultures, at times, the walls of one or two cells of the macrospores become thickened. These cells look like chlamydospores. (Plate III, fig. 3).

Sclerotia are formed on cooked rice, cooked wheat, rice-meal agar and other starchy media, especially if they are dry. On cooked rice, sclerotia are generally coloured violet or scarlet red. On sucrose agar, they may be blue or brown. In transverse sections the sclerotia show a hollow centre which may be partially filled with strands of hyphae from the cortex. The cortex is composed of pseudo-parenchymatous cells, and is ringed by a closely matted tissue, which is hard and generally coloured. Neither the development of sclerotia, nor of the pigment in them is found to be a constant character. As a rule, the sclerotia are developed in the first one or two generations after the fungus has been isolated from plants or soil, but they may appear even in later subcultures. Once they are developed, they do not necessarily continue to be formed in subsequent subcultures. The two strains described by Ajrekar and Bal* seem to be identical in every respect with our strain A. They consider their two strains to be distinct from each other, although they are identical in all other respects except the colour of sclerotia. From our work it seems doubtful if the difference in colour of sclerotia can be considered an important point in separating these strains which are otherwise identical.

STRAIN B.

This strain has been isolated from some of the wilted cotton plants from Nagpur and Hinginghat and also from " wilted " and " non-wilted " cotton fields.

On cooked rice the aerial mycelium on the surface of the medium is invariably pink in colour, which does not change even when the culture is several months old, whereas the submerged mycelium is at first violet heliotrope which changes to

* Ajrekar, S. L., and Bal, D. V. Observations on the Wilt Disease of Cotton in the Central Provinces. *Agri. Jour. India*, XVI, 1921, p. 598-617.

deep violet. This violet pigment is also taken by the rice grains. The growth is aerial, but not as much as in strain A, and is cauliflower like. On rice-meal agar it develops a light lilac colour which soon changes to pink. The aerial growth on this medium is more or less always powdery and generally confined to the surface, but it is never slimy or concentric.

Microspores measure $8\text{-}15\mu \times 2\text{-}5\mu$; average $10 \times 3{\cdot}5\mu$. Macrospore measurements on glucose agar from a 10 days' old culture are as follow :—

1—septate, $14\text{-}25\mu \times 3\text{-}5\mu$, average $21 \times 3{\cdot}5\mu$;
2—septate, $18\text{-}26\mu \times 3\text{-}5\mu$, average $21 \times 4\mu$;
3—septate, $23\text{-}50\mu \times 4\text{-}5\mu$, average $36 \times 4{\cdot}1\mu$;
∞—septate, $50\text{-}60\mu \times 4{\cdot}6\text{-}6\mu$, average $55 \times 5\mu$;

Hyphae are $2\text{-}6\mu$ broad. Chlamydospores are entirely absent. Sclerotia are very seldom formed and are brown or pink in colour, when grown on cooked rice. The growth of this strain is very rapid; almost three times as rapid as that of strain A.

STRAIN C.

This strain has been isolated only from wilted cotton plants from Nagpur and has not so far been isolated from any of the soil samples. On cooked rice it always develops a white cottony aerial growth. It is characterized by the fact that it does not develop any colour. On rice-meal agar the growth is submerged, slimy and colourless. In old cultures stray hyphae might at times become aerial.

The production of microspores is very poor. At times they are only produced when the culture is several months old. They measure $8\text{-}15\mu \times 2\text{-}5\mu$; average $10 \times 3\mu$. The development of macrospores is poorer still and their measurements on glucose agar from a 10 days' old culture are as follow :—

1—septate, $20\text{-}25\mu \times 3\text{-}5\mu$, average $22 \times 3{\cdot}9\mu$;
2—septate, $24\text{-}30\mu \times 4\text{-}5\mu$, average $27 \times 4\mu$;
3—septate, $30\text{-}48\mu \times 4\text{-}5{\cdot}5\mu$, average $39{\cdot}5 \times 4{\cdot}2\mu$;
∞—septate, $44\text{-}53\mu \times 5\text{-}5{\cdot}5\mu$, average $50 \times 5\mu$.

Hyphae are $2\text{-}5\mu$ broad. Chlamydospores are rare and are found only in some of the old cultures. They are round or elliptical, terminal or intercalar and measure $10\text{-}12\mu \times 12\text{-}14\mu$. (Plate III, fig. 8). Sclerotia are wholly absent.

STRAIN D.

This *Fusarium* has only been isolated from dead cotton plants left standing in the fields for some time. Its spore masses form a blue encrustation on the subterranean parts of the dead cotton plant. It has also been isolated from the "wilted" and "non-wilted" cotton fields.

Microspores vary in shape, are hyaline in colour and measure $9—18\mu \times 3—4\mu$, average $12 \times 3{\cdot}4\mu$. Macrospores are falcate in shape, one end being slightly incurved, hyaline in colour and are one to five septate; usually three septate. (Pl. III, Fig. 1) Macrospore measurements on glucose agar from a 10 days' old culture are as follows :—

1—septate, $15\text{-}25\mu \times 3\text{-}4{\cdot}5\mu$, average $20 \times 3{\cdot}5\mu$;

2—septate, $20\text{-}30\mu \times 3{\cdot}5\text{-}5\mu$, average $25{\cdot}5 \times 4\mu$;

3—septate, $25\text{-}50\mu \times 4\text{-}6\mu$, average $34 \times 4{\cdot}5\mu$;

4-5—septate, $38\text{-}50\mu \times 5\text{-}6\mu$, average $43 \times 5\mu$.

Hyphae are $2\text{-}6\mu$ broad. Chlamydospores are generally present in old cultures. They are round or elliptical, intercalar or terminal and measure $5\text{-}10\mu \times 6\text{-}10\mu$. (Plate III, fig. 4). In old cultures, at times, the walls of one or two cells of the macrospores become thickened. These cells look like chlamydospores. (Plate III, fig. 3).

Sclerotia are formed on cooked rice, cooked wheat, rice-meal agar and other starchy media, especially if they are dry. On cooked rice, sclerotia are generally coloured violet or scarlet red. On sucrose agar, they may be blue or brown. In transverse sections the sclerotia show a hollow centre which may be partially filled with strands of hyphae from the cortex. The cortex is composed of pseudo-parenchymatous cells, and is ringed by a closely matted tissue, which is hard and generally coloured. Neither the development of sclerotia, nor of the pigment in them is found to be a constant character. As a rule, the sclerotia are developed in the first one or two generations after the fungus has been isolated from plants or soil, but they may appear even in later subcultures. Once they are developed, they do not necessarily continue to be formed in subsequent subcultures. The two strains described by Ajrekar and Bal* seem to be identical in every respect with our strain A. They consider their two strains to be distinct from each other, although they are identical in all other respects except the colour of sclerotia. From our work it seems doubtful if the difference in colour of sclerotia can be considered an important point in separating these strains which are otherwise identical.

Strain B.

This strain has been isolated from some of the wilted cotton plants from Nagpur and Hinginghat and also from " wilted " and " non-wilted " cotton fields.

On cooked rice the aerial mycelium on the surface of the medium is invariably pink in colour, which does not change even when the culture is several months old, whereas the submerged mycelium is at first violet heliotrope which changes to

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deep violet. This violet pigment is also taken by the rice grains. The growth is aerial, but not as much as in strain A, and is cauliflower like. On rice-meal agar it develops a light lilac colour which soon changes to pink. The aerial growth on this medium is more or less always powdery and generally confined to the surface, but it is never slimy or concentric.

Microspores measure 8-15$\mu \times$2-5μ ; average 10$\times$3·5μ. Macrospore measurements on glucose agar from a 10 days' old culture are as follow :—

1—septate, 14-25$\mu \times$3-5μ, average 21$\times$3·5μ ;
2—septate, 18-26$\mu \times$3-5μ, average 21$\times$4μ ;
3—septate, 23-50$\mu \times$4-5μ, average 36$\times$4·1μ ;
∞—septate, 50-60$\mu \times$4·6-6μ, average 55$\times$5μ ;

Hyphae are 2-6μ broad. Chlamydospores are entirely absent. Sclerotia are very seldom formed and are brown or pink in colour, when grown on cooked rice. The growth of this strain is very rapid ; almost three times as rapid as that of strain A.

Strain C.

This strain has been isolated only from wilted cotton plants from Nagpur and has not so far been isolated from any of the soil samples. On cooked rice it always develops a white cottony aerial growth. It is characterized by the fact that it does not develop any colour. On rice-meal agar the growth is submerged, slimy and colourless. In old cultures stray hyphae might at times become aerial.

The production of microspores is very poor. At times they are only produced when the culture is several months old. They measure 8-15$\mu \times$2-5μ ; average 10$\times$3μ. The development of macrospores is poorer still and their measurements on glucose agar from a 10 days' old culture are as follow :—

1—septate, 20-25$\mu \times$3-5μ, average 22$\times$3·9μ ;
2—septate, 24-30$\mu \times$4-5μ, average 27$\times$4μ ;
3—septate, 30-48$\mu \times$4-5·5μ, average 39·5$\times$4·2μ ;
∞—septate, 44-53$\mu \times$5-5·5μ, average 50$\times$5μ .

Hyphae are 2-5μ broad. Chlamydospores are rare and are found only in some of the old cultures. They are round or elliptical, terminal or intercalar and measure 10-12$\mu \times$12-14μ. (Plate III, fig. 8). Sclerotia are wholly absent.

Strain D.

This *Fusarium* has only been isolated from dead cotton plants left standing in the fields for some time. Its spore masses form a blue encrustation on the subterranean parts of the dead cotton plant. It has also been isolated from the "wilted" and "non-wilted" cotton fields.

On cooked rice and rice-meal agar this fungus develops a dirty white aerial growth. The spore masses are light blue in colour, but the spores are hyaline, though the spores from the blue sporodochia on the subterranean parts of the dead cotton plant are light blue in colour.

Microspores measure $10\text{-}15\mu \times 3\text{-}4\mu$; average $12 \times 3{\cdot}6\mu$ and are abundant. Macrospores are smaller and broader than those of the other strains described above. The tips of the macrospores are slightly rounded. They are one to seven septate, usually three or four septate (Plate III, fig. 9). Macrospore measurements on glucose agar from a 10 days' old culture are as follow :—

1—septate, $13\text{-}22\mu \times 3\text{-}4{\cdot}5\mu$, average $17{\cdot}3 \times 3{\cdot}9\mu$;
2—septate, $18\text{-}26\mu \times 4\text{-}5\mu$, average $25 \times 4{\cdot}1\mu$;
3—septate, $25\text{-}40\mu \times 4\text{-}5{\cdot}5\mu$, average $32{\cdot}8 \times 5\mu$;
4—septate, $33\text{-}45\mu \times 5\text{-}5{\cdot}5\mu$, average $39{\cdot}5 \times 5{\cdot}1\mu$;
∞—septate, $40\text{-}50\mu \times 5{\cdot}5\text{-}6\mu$, average $42{\cdot}5 \times 6\mu$.

Hyphae are $2\text{-}6\mu$ broad ; chlamydospores are terminal or intercalar and measure $10\text{-}15\mu \times 8\text{-}10\mu$. Sclerotia are commonly developed on all media.

Inoculation experiments.

These experiments were conducted during the cotton seasons of 1924-1925, 1925-1926 and 1926-1927.

At the time when the inoculation experiments were undertaken in 1924 there were under study about 25 *Fusaria* isolated from different soils and wilted cotton plants, as already stated. Of these *Fusaria* only 16, which appeared to be more or less different from each other, were used for the inoculation experiments, because the remainder were definitely found to be identical with one or the other of these 16 strains. From further critical study of these strains, it was finally established in 1925, that there were really only 5 distinct strains or species.

The soil was steam sterilized for two hours at 140°C. under about 37 lb. pressure. The pots were soaked overnight in formalin solution, sun dried for a few days and then filled with the sterilized soil.

Two varieties of cotton were used for these inoculation experiments of 1924. One was a variety of *Verum* known as AK_2, which is as badly susceptible to " wilt " as *Roseum*, and the other was AK_4, a variety of *Malvensis*, which is partially resistant to " wilt ". Inoculations with each of the 16 strains were done in three series and for each of these strains in every series there were one lot of plants of AK_2 and one lot of AK_4 plants.

Series I.

The soil in the pots was heavily infected with one of the 16 *Fusaria* by mixing thoroughly in it the contents of a culture growing luxuriantly on a nutrient medium.

The soil infection was done in the middle of June, 18 days before the cotton seeds were sown in it. The pots with the infected soil were watered once daily after the addition of the inoculum.

Series II.

Soil in the pots was similarly infected in th's series as in series I, but the inoculations were done just before sowing the seeds.

Series III.

In the third series the inoculations were done when the plants were 15 days old. The roots round each of the plants were exposed by digging the soil round them. Some of the roots were deliberately cut. The inoculum was placed on the exposed and wounded subterranean parts of the plants and they were then covered again with the soil. This third series was divided into two lots, in one of which the inoculations were done only once, as described above and in the other the inoculations were repeated about once a fortnight till the end of January 1925, when the experiment ended.

All these inoculations were done in the plant house, where the pots were kept. This precaution was essential because it was found that plants in pots, when brought to the laboratory from the plant house soon became limpid and their growing points and tender shoots drooped. These plants seldom recovered. There were about 500 plants, which were either inoculated or were grown in inoculated soil as mentioned above, in addition to a number of controls. None of these plants showed any signs of " wilt ". There were a few deaths, both in the controls and in the inoculation series, but these deaths were due to *Rhizoctonia*, which that particular year was responsible for many deaths in the fields as well.

When at the end of the season, *i.e.*, six months after the soil in the pots had been inoculated, it was found that there were no deaths from " wilt ", samples of the inoculated soil from series I and II were cultured on artificial nutrient media in the same way as described previously. Along with other fungi the *Fusaria* which were used for inoculating a particular lot in the two series were re-isolated in every case. This shows that the *Fusaria* used for the inoculations remained viable in the soil, but were incapable of infecting the plants.

From a critical study of the 16 *Fusaria* used for inoculations in 1924 it was ultimately established that there were really only 5 distinct strains of *Fusaria*. These 5 strains were used again for the inoculation experiments in 1925. In addition to these, the *Fusarium,* which Mr. Kulkarni had kindly sent from Dharwar, was also used. As already mentioned above, of the 4 strains from wilted cotton plants one strain (strain A) has been isolated more often than others. Five cultures of the strain A isolated from " wilted " cotton plants obtained from five different places

viz., Nagpur and Wardha in the Central Provinces, Akola and Murtizapur in Berar and Ujjain in Central India and three cultures of the same strain isolated from " wilted " and "non-wilted " cotton soils were used for the inoculation experiments of 1925. Similarly, two cultures of the strain B isolated from wilted cotton plants, obtained from Nagpur and Hinginghat and three cultures of the same strain isolated from " wilted " and " non-wilted " cotton soils were also used.

The methods of inoculation were the same as in 1924; the varieties of cotton used for inoculations also being the same. In all, about 700 plants were inoculated, but none of them took the infection.

In another inoculation experiment, a different, method was employed. Plants grown in pots three feet high were used for this experiment. By forcing in a thick iron rod at different depths of the soil, several holes varying in depth from three feet to one foot were made in each pot. In the process of making these holes some of the roots were necessarily injured. These holes were completely filled with water containing healthy cultures of the fungus to be inoculated. For this experiment the following strains were used :—

(1) Strain A isolated from wilted cotton plants obtained from Nagpur.
(2) The *Fusarium* received from Dharwar and which as already noted is considered to be similar to strain A obtained from Nagpur and other places.
(3) Strain B isolated from wilted cotton plants obtained from Nagpur.
(4) Strain C isolated from wilted cotton plants obtained from Nagpur.

None of the plants in the inoculated pots suffered from " wilt ".

This year (1926) inoculation experiments were again repeated on the same lines as in previous years, with the exception that only one variety of cotton, AK_2, a strain of *Verum*, easily susceptible to " wilt," was tried. In addition to the 5 strains used for inoculations in 1926, 3 more strains isolated from different cotton fields were used this year. About 500 plants were used for the inoculation experiments. As in previous years, there were three series of these experiments, *viz.*, (1) series I, in which the fungus used for the inoculation was thoroughly mixed with the soil, 8 days before cotton seeds were sown in it, (2) series II, in which the fungus was mixed with the soil at the time of sowing and (3) series III, in which the soil was infected when the plants were a month old. Series I was inoculated on the 14th of July and the seeds were sown on the 22nd. Series II was sown and inoculated on the 22nd July and series III was also sown on the 22nd and inoculated a month later. The results of these experiments are interesting and therefore a detailed account is considered necessary.

The rains commenced about the beginning of July, but the sowing had to be delayed till the 22nd, because till the 18th, it rained almost every day. From the beginning of August for about six weeks there was more or less rain almost every day. During this period when the air humidity ranged between 68 to 88 per cent. the soil in pots remained constantly water logged, as the sun was hardly visible.

The cotton plants were badly affected by a *Rhizoctonia* on the leaves. This disease was common not only in our three series of inoculation experiments, but plants grown in unsterilized "non-wilted" cotton soil were also equally badly affected. Though the attack of *Rhizoctonia* was so general, still the ultimate effect of the disease was not the same in every case. Some of the plants in the unsterilized "non-wilted" soil began to die from about the middle of August and in the sterilized soil a few plants were observed to die, but only in the series I and II inoculated with *Fusarium* strain A. In series I and II inoculated with other strains of *Fusaria* there were no deaths. After the break in the continuous wet period the incidence of *Rhizoctonia* decreased and there were no more deaths in any of the pots. During this wet period, out of 200 plants in series I and II inoculated with *Fusarium* strain A only 47 plants had died.

The dead and dying plants in series I and II and in the unsterilized "non-wilted" soil were macroscopically and microscopically different from typically wilting plants. In the former case, the leaves turned brown, were crisp and brittle, and began to turn inwards from the tip towards the base and the leaf stalk remained erect. In typically wilting plants there is a drooping of the leaves due to loss of turgidity, they are soft to touch, there is a general loss of the green colour, they do not necessarily turn brown, their margins roll inwards from the sides and the leaves usually drop before they loose completely their green colour. (Plate I, figs. 1 and 2). The stem of the wilted plant begins to turn brown from top downwards and occasionally this browning may be checked and new shoots may arise from the lower nodes, whereas in the diseased plants of our experiments there was a general dying of the whole plant and there were no cases of recovery. In a wilted plant when the bark is removed, longitudinal brown streaks are visible on the wood; these were not visible in the dead and dying plants mentioned above. Transverse sections of the subterranean parts of wilted plants show typical browning of the vessels and clogging of the lumen of the vessels with some gummy substance. Again, they give typical pink colour reaction when stained with an alcoholic solution of Alizarin sulfosaur natron. Hyphae are present in the vessels but very few. In the dead and dying plants of our experiments transverse sections showed slight browning, which gave no colour reaction with Alizarin sulfosaur natron, and the vessels were filled with hyphae. In both cases *Fusarium* strain A was isolated from dead and dying plants.

Series III sown on 22nd July was inoculated on the 22nd August. *Rhizoctonia* appeared on the leaves as in other series, but in this case there were no deaths.

These experiments show once again that in "non-wilted" soil the *Fusarium* which is generally found in wilted cotton plants is present. They further prove that the mere presence of this fungus in the soil as in the artificially inoculated soils does not produce "wilt". It is evident that this particular fungus is not a virulent parasite on cotton plants, since it was found in plants, both in the inoculated and in the uninoculated series, only when the plants were attacked by *Rhizoctonia*.

This year in the unsterilized " non-wilted " cotton soil, there were a few cases of typical " wilt " during the prolonged wet period mentioned above. Out of 400 plants, 10 plants were typically wilted. These wilted plants were different both macroscopically and microscopically from the dead and dying plants of our series I and II described above. Though the same *Fusarium* was isolated from these typically wilted plants as the one from the dead plants of inoculated sterilized soil and uninoculated unsterilized " non-wilted " soil, still the effect of the fungus in both cases was entirely different.

Summary.

1. Four distinct strains of *Fusarium* spp. have been isolated from wilted cotton plants received from several places in the Central Provinces and Berar. A brief description of each of these strains is given.

2. Strain A isolated from wilted cotton plants and from " wilted " and " non-wilted " cotton soils is considered identical with the *Fusarium* received from Mr. G. S. Kulkarni of Dharwar.

3. Strains I and II of the *Fusarium* described by Ajrekar and Bal are considered to be identical and they seem to be similar to our strain A.

4. Seven distinct strains of *Fusarium* were isolated from soil samples of " wilted " and " non-wilted " cotton soils. Of these, three were found to be common to "wilted" and " non-wilted " soils, and were similar to strains A, B and D obtained from wilted cotton plants. One strain was isolated only from the " non-wilted " soil, another only from the " wilted " soil and the remaining two strains were isolated only from the field A. The eighth strain has been isolated only from some of the wilted cotton plants from Nagpur.

5. The parasitism of all the strains of *Fusaria* so far isolated from various sources was tested by inoculation experiments during the cotton seasons of 1924-25, 1925-26 and 1926-27. Inoculations were done by either heavily infecting the soil with vigorously growing cultures, one or two weeks before sowing seed, or at the time of sowing seed or when the plants were two to four weeks old. Some plants were inoculated once every fortnight for six months. None of the inoculated plants suffered from " wilt ".

6. From the inoculated soil the fungus used for the inoculation was re-isolated six months after the soil had been infected, showing thereby, that the *Fusarium* remained viable in the soil, but was incapable of infecting plants sown in the inoculated soil.

In conclusion, the writer wishes to thank Mr. J. F. Dastur, Mycologist to the Government of the Central Provinces, for the help he has given in carrying out these investigations.

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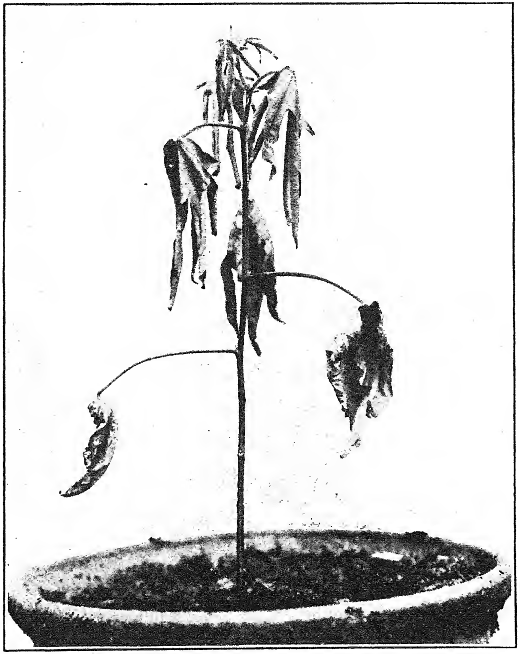
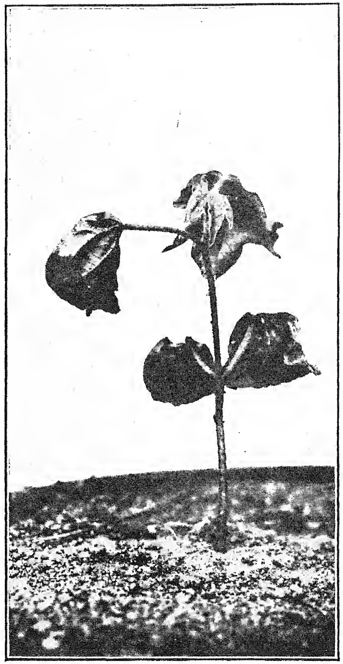
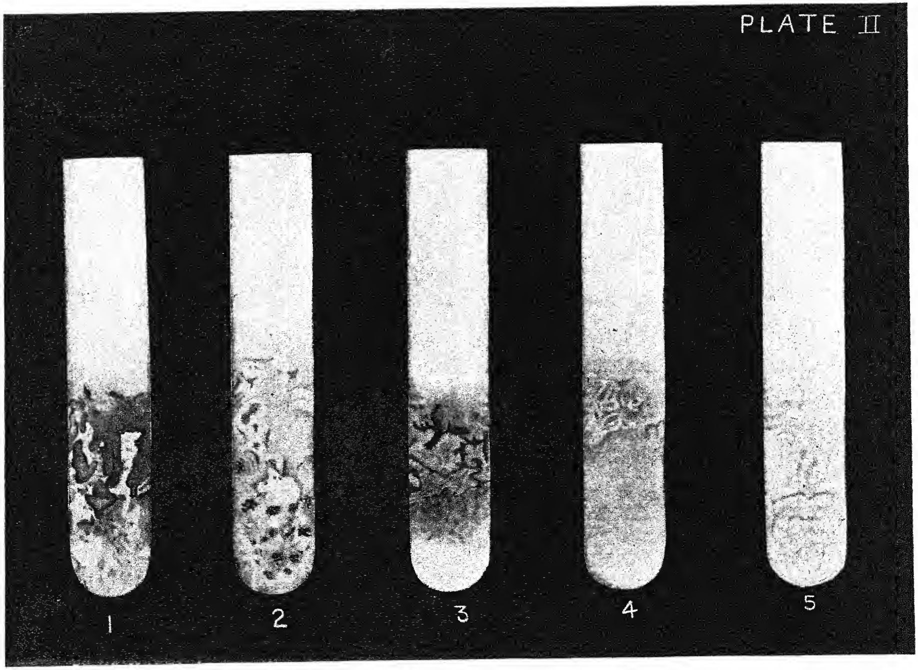


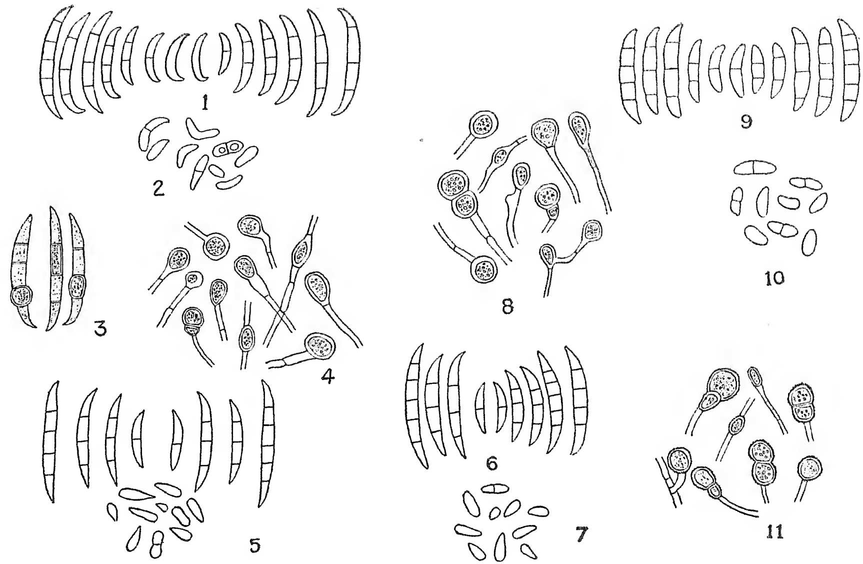
1. A typically wilting plant, variety, a *Verum* AK[illegible].



2. A plant of the same variety from inoculation series. For explanation see text.



Figs. 1 and 2, one month old cultures of *Fusarium* strain A on cooked rice. Fig. 1 shows the fungus several generations old. Fig. 2 is of the fungus in the second generation. Note the sclerotial masses in Fig. 2. Fig. 3, one month old culture of *Fusarium* strain B on cooked rice. Fig. 4, one month old culture of *Fusarium* strain C on cooked rice. Fig. 5, one month old culture of *Fusarium* strain D on cooked rice.



Figs. 1 and 2, Macrospores and microspores of *Fusarium* strain A on glucose agar from a 10 days' old culture × 450. Figs. 3 and 4, Terminal and intercalar chlanydospores from *Fusarium* strain A × 400. Fig. 5, Macrospores and microspores of *Fusarium* strain B on glucose agar from a 10 days' old culture × 400. Figs. 6 and 7, Macrospores and microspores of *Fusarium* strain C on glucose agar from a 10 days' old culture × 400. Fig. 8, Chlamydospores from *Fusarium* strain C × 400. Figs. 9 and 10, Macrospores and microspores of *Fusarium* strain D on glucose agar from a 10 days' old culture × 450. Fig. 11, Chlamydospores from *Fusarium* strain D × 450.

CONTENTS

PLATES

THE KOLAMBA RICE OF THE NORTH KONKAN AND ITS IMPROVEMENT BY SELECTION.

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I. Introduction.

The *Kolamba* variety of rice is the most important of all those grown in the North Konkan in the Bombay Presidency and the neighbouring country not very high above sea level. The chief centre of its cultivation is the Thana and Kolaba Districts. The adjoining parts of Surat, Ratnagiri, Ahmednagar, Satara and Poona take an almost negligible share in the cultivation of the variety. The actual acreage under this rice is not easy to determine. An approximate idea can, however, be formed. The total rice area in the Thana and Kolaba Districts is nearly 600,000 acres, and in the neighbouring districts it is about 200,000 acres.[1] In this area about fifteen different types of rice are grown, many of which are, however, inferior, and are only cultivated where the better kinds will not grow. Of the superior types, the authors estimate that at least 200,000 acres are covered by the *Kolamba* rice, and its cultivation is rapidly spreading wherever it can be grown.

Kolamba rice is said to owe its name to a kind of prawn called *Kolambi* or *Kolambya*, which is generally eaten with this type of rice by the fish-eating population. The rice may be said to be somewhat lacking in flavour which is given to it by the prawn in question. This theory suggests that the variety originated near the sea coast, and this is in accordance with other indications. It appears that until less than a generation ago, except near the coast, the varieties chiefly grown in what is now the *Kolamba* area were those known as *Patni* and *Tawsal* which have much coarser and less translucent grains. The *Kolamba* variety, however, became popular in and near Bombay, where it commands a much higher price than the other

[1] Season and Crop Report of the Bombay Presidency, 1923-24.

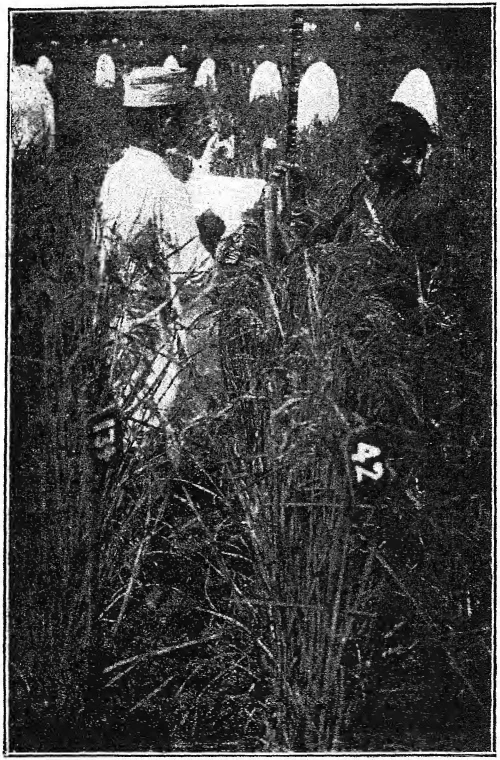
coarser and inferior sorts. It has now spread right up to the foot of the Western Ghats, but has not gone much beyond them. The area now occupied contains about eight sub-varieties of *Kolamba* rice. The differences between them will be described later.

As has already been stated, the cultivation of the variety under discussion is steadily increasing, and there is a great traffic in it to Bombay. There are numerous mills which devote themselves to hulling and polishing it, particularly in the Thana District. The finished product is often termed *Kalyan* rice, as much of it is sent out from this centre. It is largely consumed by the middle and upper class population in Bombay and its suburbs, and in Gujarat, Baroda and Kathiawad. To the cultivators, it is almost entirely a money-making crop, with a high cash value. As for their consumption, they prefer coarse types of rice which can be purchased fifteen or twenty per cent. cheaper but which are better in nutritive value. In place of *Kolamba,* they often use Rangoon rice which is generally cheaper even than the local coarse rices. The landlords often make it compulsory on their tenants to grow *Kolamba* rice, especially where there is the system of share rents, as this brings a high price in Bombay.

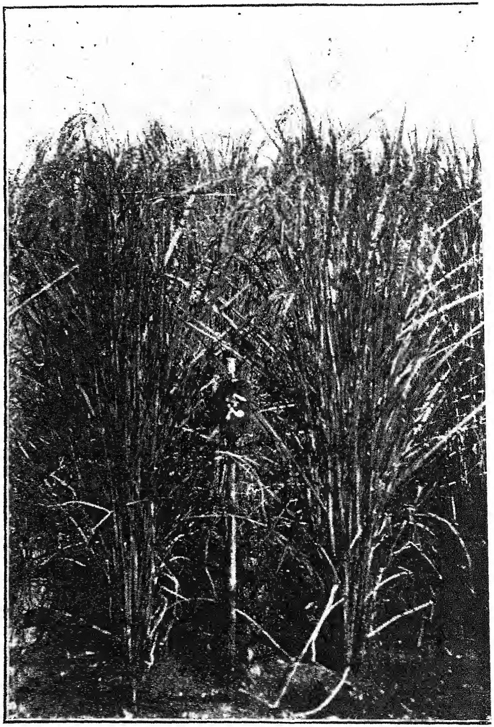
Kolamba rice is very fine, with white translucent grains. These are also hard and flinty. Though this rice has no smell or flavour, its slender and fine grains retain their general form when cooked, and do not turn into a sticky mass as the grains of the softer and coarser rices do. It also takes a fine polish in the mills, and presents a crisp and inviting appearance when served as a dish. The importance of fineness and crispness is so great that the richer classes often prefer it even to some of the scented rices like *Ambe Mohor* and *Kamod*. The former of these is not so trans'ucent and the latter not quite so fine as *Kolamba*.

Kolamba rice is, moreover, the chief type exported from the Thana Disrictt and is in demand from other parts of India, (Burma, Madras, Sind, Gujarat, Kathiawad) and from other countries (Arabia, Persia, East Africa, Natal, Zanzibar, etc.). In the latter case, it is taken apparently for the use of the Indian population. The actual exporting centres are Bombay, Bhiwandi and Panwel, and direct cargoes go even from the latter places as far as Kathiawad.

The average yield of the rice crop per acre in the North Konkan may be taken at about 2,000 lb., and the crop is very regular and certain. What with high rents and high costs for labour, the margin of profit to the actual cultivators, however, is not very great, and as a result, it is important that the yield per acre should be increased. This can, of course, be attained by more intensive cultivation and manuring and also by the selection of types of seed which give a higher yield per acre. The former method of increasing the produce per acre does not affect us here, but the latter method has been successfully followed in the work to be described in the present paper. The basis of the selection undertaken has been bulk samples received from the cultivators of the *Kolamba* area, which have proved themselves mixtures of widely differing types of very different economic value.



1. Showing the method of recording plant to plant measurements and observations, and of bagging to prevent natural crossing.



2. Showing all tillers reaching nearly the same height, and the erect nature of the plants

The work to be described was commenced in 1918 by the late Mr. H. M. Chibber, but he, unfortunately, did not live to see the results of his labour. After his death, the work was continued by the present authors. When commenced, it was carried out at two centres, namely Alibag in the Kolaba District, and Jambul in the Thana District. In 1919 the whole was transferred to a rice research station established at Karjat in the Kolaba District and the present authors have carried it on at this centre since 1921. This centre is very representative of the *Kolamba* rice tract. The basis of the selections were bulk samples collected in large number in Thana, Surat and Kolaba in 1918, 1919 and 1920. The methods used in growing the samples were those of the district with only such deviations as were needed for experimental accuracy, or for facility in uniform transplanting and even spacing. Thus, single plants alone were used for transplanting, and they were put in straight lines with enough space on each side for easy movement for observation. The plants intended for seed purposes have always been bagged (Pl. I, 1) since 1920 to maintain their purity by preventing natural cross fertilization.

From the bulk samples grown in 1918, 210 plants were selected on the basis of morphological characters supposed to have a more or less direct bearing on high yield and earliness. Rough yield comparisons have been carried on since 1919. They were at first based on the produce of an equal number of plants in the different cultures. The number of plants forming the basis of comparison was 200 in 1919 and 1,200 in 1920, in which year each culture was repeated six to nine times over the experimental area. On working out the yield comparisons of the 1920 crop, ten samples gave promise of being useful. Of these, eight were promising in yield and fineness of grain and two were very early in ripening though coarse in grain size. The purity was not, however, certain and an elaborate programme was adopted in 1921 and 1922 to determine and maintain the purity of the types, and to study them closely under uniform conditions in the various cultures. These plans involved detailed notes on the various cultures, regarding special features, and plant to plant measurements, weights and counts in the field and in the laboratory of all the important characters of the different types. This has enabled a very high standard of purity to be reached among the types, while numerous replications of every important selected type with the usual cultivators' seed have given the possibility of very accurate comparison of yield.

II. The Kolamba rice : the material for selection.

The *Kolamba* rice is known by three names in different parts of the tract where it is grown. These are (1) *Kolamba,* the most common name, and one recognised everywhere, (2) *Rata,* or *Tambada,* a name chiefly used in the Thana District, and chiefly, if not exclusively, employed to denote the reddish husked, comparatively coarse and somewhat inferior types generally and (3) *Bhurya,* which is also chiefly used in the Thana District, and specially denotes the pale husked fine superior types, also known as *Zinya.*

The above are names in common use. But there are a number of well recognised agricultural types, distinctly separated by the growers of the variety, whose characteristics are noted below :—

1. *Mahadya.* This is a tall type with a long panicle carrying a comparatively small number of branches and a smaller number of large sized grains. This is at present grown in certain parts of the Kolaba District only. Its cultivation is steadily decreasing on account of its coarseness and slight lateness in ripening.

2. *Ghudya.* This type is somewhat finer. Its panicle is rather compact, for which reason it is called *Ghudya* or cluster-grained. The husk is reddish in colour, whence it is also classed with the *Rata* or *Tambada* types, both of the terms meaning red. This can be grown with success on soils of medium fertility. It is reported to yield better than the *Zinya* types, to be mentioned next. But it commands a slightly lower price in the market for the reason of its comparative coarseness. This type is generally late and takes about 150 days for ripening.

3. *Garwa Zinya.* This is the finest type in cultivation and in the market. The colour of the foliage is light green, and of the ripe husk pale yellow. The grain is rather short, pronouncedly slender, and the tips of the kernel are pointed. This is said to require a balanced condition of the soil as regards manure. In fields with ordinary fertility it yields rather poorly, whereas in fields that are extra rich it turns to leaf and is spoiled badly. It ripens about a week earlier than the *Ghudy* type. The husk fits the kernel rather loosely and is easily separable. It also shows a smaller proportion of husk to kernel when compared with other types, and for all these reasons it commands a higher price in the market.

4. *Halwa Zinya.* This ripens about a fortnight to three weeks earlier than the *Garwa Zinya* described above. It can be grown with success on lands which are extra rich in fertility and where other types would invariably run to leaf. Thus this type does not suffer from heavy manuring, but under such conditions yields a fairly heavy crop, matching the late type in the matter of yield. It requires, however, very timely harvesting, otherwise it suffers from shedding of grains in the field and their breakage in milling. The grain is longer and more slender than that of the *Garwa Zinya* and consequently may command even better prices than the latter.

5. *Halwa Ghudya,* also called *Tokadya.* This is a reddish husked type comparable to the *Ghudya* described under No. 2 above. The only difference between the two is the time of maturity, the *Halwa* type maturing about two or three weeks earlier than the *Garwa* type.

6. *Korkadya.* This type may be described as almost similar to the *Ghudya* type. It is doubtful if it is at all distinct from it. It may differ in the time of maturity, as the cultivators say that they grow it to distribute their harvesting over a longer period. In this type the grain colour is just the same as that of *Garwa Ghudya,* but in size and shape the grain is rather short and blunt at the ends, besides it matures about ten days earlier than the *Garwa Ghudya.*

7. *Kachanya.* This is similar to *Korkadya* except that its grain is slightly thinner and the two ends of the kernel are slightly more pointed.

8 and 9. *Kasadya and Javarya.* These two types are particularly early. They ripen about one month in advance of other types. In grain size they are pronouncedly coarse and have comparatively thick kernels. They are grown on high lying lands. They are a source of ready money to the cultivator in the early part of the season, as they have a ready market. The dealers purchase them as they are cheap for mixing with the costly superior varieties.

Defects of the Kolamba rice crop. As has already been noted, this valuable commercial variety of rice is a recent introduction, and hence its defects as compared with other types are well recognized and often discussed. The cultivators complain that fine grains are generally associated with low yield, and that in certain seasons particularly there are many unfilled grains on the heads. Further, where the fields are very rich, the crop is said to run to leaf and to produce many uneven and unproductive tillers, so that the ripening is uneven. Again, it is said often to have weak straw, and hence to be apt to lodge so that the grain is damaged. In addition to these defects, it is liable to shed the grain badly if slightly over-ripe and to be very sensitive to a shortness of water during the growing season. It is also liable sometimes to the attacks of the stem borer which causes many earheads to remain unfilled.

The miller who husks and polishes the grain complains of *Kolamba* rice that it is not uniform in size of grain and hence does not polish well, and further that it is apt to much breaking of grain during the milling operations. This means, of course, that the *Kolamba* rice is not even, as brought to the mills, so that the coarser grains are broken and finer ones escape the polishing process.

It is obvious from these complaints that any selection must take account of the defects indicated, and that the aim must be to obtain an even type suitable, as regards fineness, time of ripening and high yield. It should be strong in straw, little affected by excess of manure or by shortage of water, and should not shed the grains seriously if slightly over-ripe. It should also resist the attack of the stem borer.

The need of such an even type with these characters is recognised in the *Kolamba* growing areas. The better cultivators take a good deal of pains to reserve what they consider as the best of their seed for cultivation, though this best may often be so only in appearance. Their methods of selection are two. One consists in collecting such grain as drops down near the stack while the sheaves heaped there are being removed to the threshing yard, and using this for seed purposes. The idea in this case is that the seed that drops in this way is likely to be heavy and well developed and hence better suited for sowing purposes and for securing a good yield. The other method consists in selecting large and heavy earheads from the sheaves in the threshing yard for seed purposes. Both these methods are obviously used with the idea of getting high yield either by the use of heavy grain for seed, or by obtaining heavy earheads irrespective of the other important characters of

the plant. Owing to the frequent occurrence of cross-fertilisation in this region and to the fact that the types in cultivation are, hence, more or less impure, the effect of these methods in producing pure breeding plants with large outturn and other desirable characters is very limited. Selection of the plant in the field, based on its various valuable inherent characters including tillering, is not, in the authors' experience, carried on in the *Kolamba* area. The limited selection adopted has, apparently, resulted in obtaining a predominance of types either with extreme fineness of grain or peculiar colour of husk which are found in certain parts of the area. Thus it has resulted in some cases in an improvement of quality rather than in yield.

The ideal type of Kolamba rice. Considering the conditions of growth and the demand of the market, it is possible to indicate in some detail the type of plant which selection should aim to obtain.

From the morphological point of view, the ideal *Kolamba* rice should have a medium height and a thick erect culm. Tall and thin stemmed plants, and plants with a bending and spreading habit are easily swayed by the wind and are hence more likely to lodge. Leafiness should only be moderate, as excessive development of leaf would be very objectionable in highly manured fields near village sites or forest areas. A strong tillering habit is an advantage, provided the tillering is rapid and the earheads on the tillers reach about the same height as the main panicle and ripen about the same time as the latter. Otherwise, there is unevenness in ripening, and loss of quality and yield. This is a matter of special importance in a somewhat free tillering variety like *Kolamba*. Uneven ripening means shedding of the grain in the earlier formed earheads, or a large amount of breakage in milling of the unripe grains.

The leaves of the plant should be glabrous, as there seems to be some correlation between hairiness of leaf and coarseness of grain. The peduncle should be rather short, as long peduncles are likely to break and to prevent the proper development of grain. The panicle should be long, large, compact and heavy, and have few or no sterile grains, while the grains themselves should be fine. Awnless types are to be preferred to awned ones.

The ideal type of *Kolamba* rice for the Thana and Kolaba Districts should mature within about 140 days. In the strains so far found very early maturity means poor production and very lateness is risky owing to shortage of water.

The type selected should be easily hulled, and should have a white kernel, so as to cause less labour in polishing and less waste in the finished product.

III. Botanical description of the Kolamba rice and its variations.

The *Kolamba* rice belongs to *Oryza sativa* var. *communis* (Kœrnick) sub-variety *media*. The spikelets are elongated, their length being more than three to four times the breadth. In shape they are sub-linear or narrowly elliptic-lanceolate, the palea being nearly straight and the flowering glume only slightly convex at the

back. The *Kolamba* plant is free from anthocyanin pigment, *i.e.*, there is no reddish or purplish colour in the sheath or any other part of the plant. It is free from awns also. The husk when ripe is pale yellow to rusty reddish brown. The kernels or grains are generally translucent and flinty, and more or less white in colour. They are devoid of smell.

There is a great deal of variation in almost all the characters of the *Kolamba* variety. It can be divided into a number of more or less distinct botanical types. As mentioned before, several types are already known to the cultivators and the people at large and a considerable number of sub-types of an elementary nature have been separated and maintained at the Rice Breeding Station at Karjat.

Thus it will be seen that the name *Kolamba* is rather loosely applied to a large number of strains which are distinct from each other. The main points, however, in which they resemble each other are (1) the slenderness of the spikelets and grains, (2) the linear to elliptic-lanceolate shape of the spikelets and grains (3), the reddish or brownish yellow colour of the husk, (4) the translucence of the grain, (5) the flintiness of the grain, (6) the whitish colour of the grain, (7) freedom from anthocyanin pigment throughout the plant, (8) absence of awns and (9) lack of smell.

Classification of the various characters. In order to make a detailed study of the various characters of the *Kolamba* variety as a whole it would be convenient to divide them into two classes, *viz.*,vegetative and reproductive. These will, therefore, be dealt with separately.

It may be stated here that the characters described below have been observed in pedigree cultures of the original selections both in the laboratory and in the field for more than three successive generations, and though they are subject to slight fluctuation owing to conditions of nutrition, growth, etc., they may be safely taken as the expression of hereditary qualities of the various cultures.

VEGETATIVE CHARACTERS.

Germination and rate of growth. In folds of wet blotting paper the seeds of the different strains take from 30 to 45 hours for the husk to rupture and for the radicle to emerge. In field conditions the plumule shoots out in the form of a needle within about 72 to 96 hours from sowing if the seed beds are properly wetted by rain. The first leaf unfurls within 150 to 170 hours. Two of the authors' strains Nos. 79 and 110, which have coarse grains and mature very early, that is to say 30 to 35 days in advance of the majority, generally showed a quicker unfurling of the leaves and had a stronger growth in the first week. But there cannot be said to be a very appreciable difference in the time taken by the different strains to germinate and for their early growth. Some of the very late strains also, such as Nos. 103 and 104 which mature about 10 days later than the late strains, do not seem to be slow in their germination and early growth. On the other hand, No. 184, another very

early strain, but with finer grain, is not so vigorous in its growth as other early types like Nos. 79 and 110. There is therefore no reason to suppose that the early maturing strains have necessarily a much quicker and the late ones a slower rate of growth in their seedling stage or for the first three weeks or so. Their behaviour on resuming their growth after transplanting, *i.e.*, from August 1st, is however remarkable, inasmuch as the very early ones show a markedly greater rapidity in attaining the limit especially of their height, and perhaps, though less markedly, in producing tillers and respective leaves. This will be seen clearly from the three Tables given below :—

TABLE I.

Showing the rate of growth in height of the different strains of Kolamba as indicated by the average heights of plants upto the joint of the first leaf from top, measured at successive one week periods in cm.

Periods	STRAINS										
	VERY EARLY		INTERMEDIATE		LATE					VERY LATE	
	No. 79	No. 184	No. 153	No. 164	No. 32	No. 35	No. 39	No. 42	No. 121	No. 103	No. 104
August 1, 1924 . . .	16·6	18·0	16·8	15·6	16·0	14·4	15·0	13·8	15·2	14·4	16·4
" 8, " . . .	18.4	20·2	18·0	17·8	18·2	17·0	18·0	15·6	18.6	17·2	17·6
" 15, " . . .	24.4	23·8	20·4	19·4	18·8	18·8	20·0	17·2	21.2	19·2	19·4
" 22, " . . .	32·4	28·0	22·4	21·2	21·6	20·0	21·2	18·4	22·8	20·8	20·8
" 29 " . . .	50·8	40·0	26·4	26·8	26·0	26·0	26·4	25·2	26·8	25·6	24·8
September 5, 1924 . . .	77·8	61·0	32·0	28·2	27·2	27·2	30·2	26·0	31·2	28·4	26·6
" 12, " . . .	100·0	77·6	36·0	33 0	31·2	31·4	35·6	28·6	35·0	31 0	29·8
" 19, " . . .	101·2	78·8	47·8	44·4	37·4	38·0	41·6	31·4	37·2	33·0	31·
" 26, " . . .	..	..	74·6	71·0	46·8	49·2	50·0	39·2	45 4	39·0	36·2
October 3, 1924 . . .	..	..	98·6	97·2	64·2	68·4	84·0	53·4	57·2	47·2	41·4
" 10, " . . .	..	..	..	..	88·8	90·4	102·2	77·0	80·2	60·2	50·4
" 17, " . . .	..	..	..	..	..	..	..	115·8	144·8	75·8	72·6
" 24, " . . .	..	..	..	..	..	..	..	..	148·0	110·2	115·2

The very early strains show a very rapid progress in attaining the limit of their height.

TABLE II.

Showing the rate of growth as indicated by the average number of tillers per plant produced by the different strains of Kolamba at successive one week periods.

Periods	STRAINS										
	VERY EARLY		INTERMEDIATE		LATE					VERY LATE	
	No. 79	No. 184	No. 153	No. 164	No. 32	No. 35	No. 39	No. 42	No. 121	No. 103	No. 104
August 1, 1924 . . .	1·4	1·0	1·0	1·4	1·0	1·0	1·0	1·0	1·0	1·0	1·0
" 8, " . . .	2·4	2·0	2·6	2·4	1·2	1·6	1·8	1·7	1·4	1·6	1·8
" 15, " . . .	4·0	3·2	4·4	4·4	3·0	3·4	4·2	3·5	2·6	3·4	3·6
" 22, " . . .	5·8	5·6	8·2	7·2	5·8	4·8	6·6	6·0	4·4	5·4	6·4
" 29, " . . .	8·2	6·2	9·8	8·2	8·2	5·4	7·2	6·7	6·2	7·2	7·6
September 5, 1924 . . .	8·2	6·8	10·4	8·6	8·2	6·0	7·8	7·0	6·4	7·0	8·0
" 12, " . . .	8·4	6·8	10·4	8·8	8·2	6·6	8·0	7·5	6·6	7·0	9·4
" 19, " . . .	8·6	6·8	10·4	9·0	8·2	6·8	8·0	8·0	6·8	7·6	10·0
" 26, " . . .	8·6	6·8	10·4	9·2	8·4	6·8	8·0	8·0	6·8	7·6	10·2
October 3, 1924 . . .	8·6	6·8	10·4	9·2	8·4	6·8	8·0	8·0	6·8	7·6	10·2

The very early strains show better progress in this respect for the first three weeks or so, but later on the other strains are seen to make up the growth as **the early strains are generally poor in tillering.**

TABLE III.

Showing the rate of growth indicated by the average number of leaves per plant including all the tillers produced by the different strains of Kolamba at successive one week periods.

Periods	STRAINS										
	VERY EARLY		INTERMEDIATE		LATE					VERY LATE	
	No. 79	No. 184	No. 153	No. 164	No. 32	No. 35	No. 39	No. 42	No. 121	No. 103	No. 104
August 1, 1924 . . .	5·8	4·6	5·2	5·2	4·8	4·6	4·4	4·6	4·4	4·6	4·4
„ 8, „ . . .	9·6	7.2	9·4	7·8	5·4	7·6	8·0	3·3	6·6	7·0	7·2
„ 15, „ . . .	16·2	11·6	16·0	15·0	11·8	12·4	14·0	11·8	10·2	12·4	12·2
„ 22, „ . .	24·0	19·8	27·0	23·4	20·4	20·2	21·6	20·0	16·6	20·2	21·0
„ 29, „ .	31·4	23·8	36·2	29·4	27·4	25·2	29·0	25·2	22·8	27·0	27·4
September 5, 1924 . . .	35·6	28·4	45·8	37·0	37·0	32·6	35·8	32·0	28·0	34·4	36·2
„ 12, „ . . .	36·4	29·2	50·4	40·2	42·6	36·4	37·4	37·0	32·2	38·4	43·0
„ 19 . . .	36·8	30·6	56·6	48·6	44·0	40·0	43·2	40·2	35·8	43·0	40·6
„ „ . . .	37·8	33·8	63·6	56·0	54·6	52·8	57·2	48·8	46·6	53·0	55·2
October 3, 1924 . . .	..	..	64·6	57·4	59·4	55·2	59·6	51·0	54·4	56·0	62·4
„ 10, „ . . .	..	..	..	..	59·6	55·8	..	51·8	55·6	60·4	69·0
„ 17, „ . . .	..	..	..	..	..	..	..	..	56·8	61·4	74·0
„ 24, „ . . .	..	..	..	..	..	..	..	..	..	..	..

The very early strains show better progress in this respect for the first four or five weeks, but later on the other strains make up the growth for reasons already given under Table II.

Tillering power. This character is of considerable economic importance as it is closely connected with the yield finally obtained. The rice plant begins to tiller within about fifteen days from sowing, provided the seeds are not sown very deep and thickly. Tillering is shown more markedly by certain strains than others even under uniform conditions of space and plant food. Tillering often varies with the total length of time required for maturity in the *Kolamba* variety, the early strains being poor and the late ones richer in tillering.[1] (Table IV). In another variety called *Patni*, also grown in the Konkan, however, which is as late as the late *Kolamba* types, the tillering is much poorer. But the grains in that variety are far coarser as compared with *Kolamba* and the earheads are also large and heavy, so that this variety seems to utilize the food materials absorbed in producing larger earheads and grains and not in producing numerous tillers. Late maturity and high tillering are, therefore, not necessarily correlated in *all varieties.* In comparative trial plots the mean tillering of the very early *Kolamba* strains, taking 115 days to mature, was five per plant transplanted at eighteen inches by nine inches apart, whereas in the very late strains taking 160 to 165 days it was as high as 14 when the plants were similarly spaced. But leaving aside these extreme periods of maturity the mean tillering of a large number of strains maturing within 135 to 150 days varied from 7·7 to 11·2 per plant in 1922, spaced in the way described.

Tillering also continues to a variable period in the life of a plant. The result is that in certain strains there is a variable number of unproductive tillers which on account of their very late development fail to produce panicles or well developed grains, and at the most only add to the straw. This number of sterile tillers varies from 0·3 to 2·7 per plant on an average in the different strains under conditions mentioned above. The percentage of sterile to fertile tillers varies from 7 to 22 in the different strains. This feature of continued and late tillering is objectionable but can be checked by planting closer, together, whereby the production of such late tillers would be checked and the energy of the plant utilized for the production of more grain.

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[1] Jacobson, H. O. Correlative characters of the rice plant: *Philippine Agricultural Review*, Vol. IX, page 115.

Thompstone, E. Some observations on Upper Burma Paddy. *Agri. Jour. of India*, Vol. X, pp. 36-37.

TABLE IV.

Showing total tillering in the different strains varying more or less according to days to maturity.

Strain No.		1921	1922	1923	1924
Very early	79	8·4	5·02	4·61	6·79
Intermediate	153	..	11·20	8·70	9·39
"	164	..	10·52	7·79	7·87
Late	32	14·90	9·70	8·78	9·51
"	35	13·10	7·70	7·68	8·73
"	42	11·62	9·90	9·80	10·52
"	121	..	9·06	..	7·52
Very late	104	..	14·10	10·57	11·30

A closely related feature is the height which the successive tillers attain in a plant. In certain strains all the tillers may reach nearly the same height, by the time the panicles are mature, (Pl. I, 2), whereas in others the mother culm grows taller than the other tillers which individually reach a variable height. The latter feature is undesirable as it entails greater unevenness in the size of earheads and in maturity and the consequent loss of grain. These defects seem to be associated with very profuse tillering.

Another noticeable feature is the angle made by the different tillers with the mother culm and with each other. In certain strains the tillers are all nearly erect and the bunch is a close compact mass forming a narrow inverted cone, whereas in others they spread a good deal and the shape of the bunch is like an inverted cone with a wide angle. The latter strains in the authors' experience are more likely to lodge.

Colour tint of the foliage. This is a fairly constant feature of the various strains of *Kolamba* rice. It can be clearly seen as a mass effect in the field within about ten or fifteen days after sowing. It varies from light to yellowish green to medium or dark grayish green in the different strains. Although there are fluctuations due to space, food supply, etc. and though the better nourished plants are darker in colour, still the relative values of the different strains remain nearly the same under uniform conditions. Strain No. 223, exceptionally, however, has rather a pale yellowish colour just a few days after germination, but later on the colour becomes

more dark by exposure, so that the tips of the leaves are darker than their bases in the early stage of the seedlings. There seems to be some evidence, which, however, requires further confirmation, that the lighter coloured strains require a slightly lower temperature for flowering than the darker coloured. Thus while the former had many of their flowers open at 80° F., the latter commenced to open at 84° F. only. Similarly as the day advanced and the temperature rose at 11-30 A.M. to 86° F., the latter showed full flowering but the former only to a very small extent.

Plant height. The height of the mature plant in the different strains varies considerably even under closely similar conditions, the range being from 110 to 170 cm. when measured from the surface of the soil to the tip of the panicle straightened out. The measurement should, of course, be made on the mature plant only, as the early strains put forth their culm earlier.

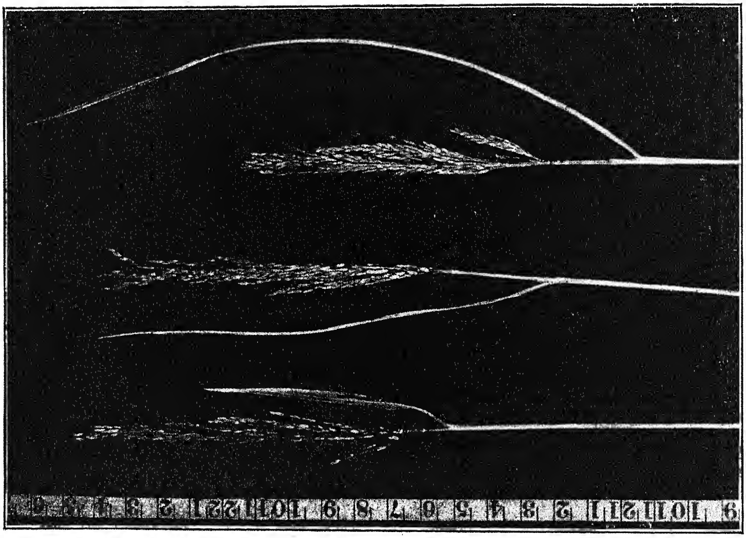
Thickness of the culm. This has been measured at the middle of the first internode above the ground. It is again a rather variable character being greatly influenced by food supply, the range being from 6·5 to 7·7 mm. in diameter. There does not seem to be any correlation between the thickness of the culm by itself and the standing power of the plant at maturity.

Number of internodes or leaves. This is a character of relative stability though it varies according to the time of maturity of the strain. In the very early strains the number of internodes or leaves is about ten to eleven including the extremely compressed ones just below or at the ground level. But in the very late strains it is eighteen or nineteen. The following table shows the number of internodes or leaves on the main culm in different strains :—

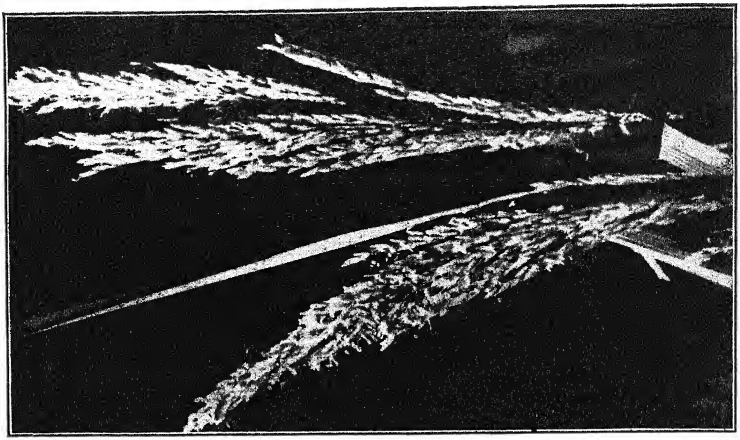
TABLE V.

Showing the number of internodes or leaves on the main culm.

Strains	Number of internodes or leaves
Early strains—	
No. 79	10—11
No. 184	10—11
Intermediate strains—	
No. 153	14—15
No. 164	14—15
Late strains—	
No. 32	16—17
No. 35	16—17
No. 39	16—17
No. 42	16—17
No. 121	16—17
No. 104	18—19



1. Showing types with different flag lengths as compared with the tip of the panicle.



2. Showing panicles of the *Kolamba* rice in flower.

The length of the flag (or the Uppermost Leaf). The range of variation in this respect is from 23 cm. to 44 cm. when measured from the ligule to the tip of the leaf. In certain strains the flags are generally large, while in others they are comparatively small. The flag is often a good index of the size of the leaves of the plant in general.

The breadth of the flag. The range in this respect is from 1 cm. to 1·5 cm. when measured at the widest part, some strains being proportionately broader-leaved than others.

The flag is generally shorter than the two or three leaves next below, but it is generally the broadest leaf of all. With reference to the tip of the main panicle the tip of its flag may go higher in some strains, reach about the same level in others, or remain shorter in the rest (Pl. II, 1). Its size and the position of its tip are slightly affected by the nature of the soil and the nutrition of the plant. In rich soils the flags and the leaves are longer and broader, whereas in poor soils they are shorter and narrower. The length of the peduncle, to which reference will be shortly made, is also partly responsible for the fluctuation regarding the position of the flag-tip, as it is also affected by soil conditions. But even apart from this, the position of the flag with reference to the tip of the panicle is a fairly constant strain character. As maturity advances, the flag generally droops more or less, but in certain strains it has been found to maintain an almost erect position to the last. This erect position of the flag is found very often to be associated with standing power or strength of straw. It is a very distinguishing feature of certain strains, as in Numbers 8, 164 and 104. In certain other strains the flags assume a more or less horizontal position or are inclined downwards. Such strains have a tendency to lodge as in Nos. 153, 32 and 39. In certain strains the tips of the flags are a little lighter green in colour than the lower part and look somewhat hardened and spiney at the extremity. In many cases, the flag has a peculiar constriction about an inch or so below the tip, whereas, in a few cases, it has been observed to get twisted and thrown into two or three curls. In some cases, the leaves show a slight tendency to roll when the sun is strong. The exact significance of some of these characters is yet unknown, though the last two may be devices for shunning the strong light and attendant heat.

The hairiness on the leaves. This serves as a diagnostic character of the different strains, but it has to be examined at a particular stage of the plant. At an early stage the hairs are not fully developed, while at a very late stage they fall off. They can be seen well about the middle of August, that is to say, when the plants are 65 to 70 days old. When present normally, they are more numerous on the upper surface of the leaf than on the lower. Some types of the *Kolamba* variety are absolutely or practically glabrous in their leaves, but in others, the leaves are sparsely and in still others more or less thickly covered with hairs. In leaves which are very thickly hairy, the lower surface is also hairy to a certain extent. The hairs may be short and downy or long and coarse. Occasionally, there is a mixture

of both types together. It is very often found that the markedly hairy types are also rather coarse-grained.

The peduncle. This is the uppermost internode of the plant supporting the panicle and is the longest of all. The major part of it remains covered up by the sheath of the flag. But, for convenience, that part of it which emerges above the leaf joint is called the peduncle proper. Its length is a strain character, though it is liable to fluctuate under different conditions. In rich fields there is a good deal of leaf growth and hence the length of the peduncle or its emergence above the sheath appears less, while in poor fields the leaf growth is less and the exposure of the peduncle is greater. In years of poor crop growth also, the emergence is more appreciable than in years of good growth. Similarly the successive tillers in a plant show a greater emergence of the peduncle as the later tillers are obviously weaker than the main, and have shorter sheaths. The range of variation in the length of the peduncle is 1·2 cm. to 12 cm. It is not desirable to have a very long peduncle, as it is likely to break and so to prevent the proper development of the grains.

Reproductive Characters.

Dates of flowering. The dates of flowering in the different strains of *Kolamba* rice range over a period of about 45 to 50 days. This long range is of great practical importance from the point of view of the moisture conditions of different fields and of the even distribution of the available labour. The earliest types flower by about the beginning of September if sown in the first or second week of June, that is to say, in about 80 days from sowing, while the latest types take as much as 130 days, flowering about the middle of October or even slightly later. This range of abont 40 to 50 days can be roughly divided into five periods of flowering. The first of these ends about September 6th and covers just a few types only. The second period ends by about September 22nd and is not much bigger in the number of types it covers. The third period may be taken to end with the month of September and includes a larger number of types. The fourth period ends with the first week of October and covers the largest number of types in the variety. The fifth and the last period is an insignificant one including only a very few types. These five periods may be called respectively very early, early, medium, late and very late, and may be shown in a tabular form as below :—

Name of period	Range of the period	Days from sowing	Types contained
Very early	25th August to 5th September	80—90	A few.
Early	6th September to 20th September	90—105	A small number.
Medium	21st September to 30th September	105—115	A considerable number.
Late	1st October to 7th Otcober	115—122	A very large number.
Very late	8th October to 15th October	122—130	A few.

This classification is made by taking June 6th as the date of sowing when generally the first showers are received, and is based on the mean dates of flowering of the several strains under study. In line cultures an individual plant was considered to have flowered when the top portion of its panicle emerged above the sheath. In the course of the last five or six years, the strains have flowered at almost a fixed date with very slight seasonal variations, although the time of sowing may have varied by about a week or so. Even such a delay in sowing, as of two months in the case of a late strain, put off the flowering date at the most by about a week and made almost no difference in the date of harvesting although the crop was a very poor one.

The period for which the plants in a single culture (generally exceeding 200 plants in our work) continue to flower is generally longer for the early strains and much shorter for the late ones, probably because when the early strains flower in September, there is much moisture in the soil, the air is more humid and the sun's heat also is not so strong as it is in October when the late strains flower. The maximum shade temperatures during the first week of September and the first week of October actually recorded were 92°F. and 97°F. respectively.

The date of flowering of a plant in a culture is a pretty reliable indication of the purity of the culture if it does not go beyond the normal range. Any unusual extension of this range on any side may be looked upon with suspicion, and in such cases it is generally possible to find confirmatory evidence about the impurity of the culture in the matter of some other characters also. Thus it often helps in roguing an ordinary field sown with a pure type.

The period between flowering and ripening is also a fairly constant one, being about four weeks for the early strains and three weeks for the late ones.

As already mentioned the practical utility of the various strains of *Kolamba* flowering over such a long period is very great. It makes the variety suitable for the varying nature of the soil, the varying nature of the water supply, and the cultivator's need of evenly distributing the available labour for transplanting and harvesting, and the cultivator takes full advantage of it by growing strains with different periods of flowering in different kinds of fields.

Pollination. The study of pollination in the rice plant and in particular in the *Kolamba* variety in the North Konkan may be taken up next. It may enable us to make a proper estimate of the chances of maintaining the purity of a type under field conditions. In rice generally, and in the *Kolamba* variety also, self-pollination seems to be the general rule, though occasional cases of natural cross pollination are also met with. The percentage of natural cross-pollination, however, does not seem to be very appreciable, only about two to four per cent. of its occurrence being noted.[1]

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[1] Parnell, F. R. Rangaswami Iyengar, G. N.; and Ramiah, K. The inheritance of characters in rice. *Mem. Dept Agri. India, Bot. Ser.*, Vol. V, No. 7

Hector, G. P Notes on pollination and cross-pollination in the common rice plant, *Oryza sativa*. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. VI, No. I.

Researches with the rice plant, Van der Stock in Java.

In a rice plant which is about to flower, the panicles from the successive tillers are not all at the same height, nor are they all ready to flower the same day. The taller and the more central tillers being more advanced are the first to flower. In the individual panicle the flowering proceeds from above downwards. (Pl. II, 2) A few of the topmost spikelets on the branches open first, the lower ones and those on the lower branches opening daily in gradual succession. Though some irregularity in this respect may be noticed here and there, still the general order is not much interfered with.

As a general rule, a panicle takes about five to seven days to finish the opening of the flowers from top to bottom according to the prevailing weather conditions and the nature of the strain, such as early or late. At Karjat, the opening of the glumes generally takes place from 9-30 to 11-30 A.M. Most vigorous flowering is seen between 10 and 11 A.M. A few stray cases may be seen as late as 12 noon. Sometimes, if the day is a rainy one and the temperature lower than usual in the morning, flowering may continue up to 2 P.M. Late in October when the days are particularly warm, the flowering may take place once more in the evening between 4-30 and 5-30 P.M., but such cases are almost negligible.

The glumes take about seven to eight minutes to open fully from the time they begin to show the least sign of parting. When fully open they make an angle of 30-35 degrees with each other. They remain open for about 45 to 50 minutes and then close up within about five minutes or so. The entire period from the beginning of the opening to the closing of the glumes occupies about 55 to 60 minutes. The temperatures at which flowering takes place range from 80°F. to 95°F., the optimum being 85°F. for the early varieties and 90°F. for the late ones.

In the course of the flowering period during a single day the flowering is in certain waves so that there are moments when several flowers on a panicle may open at once, then a few more after a short while, and again a few more and so on.

In the earliest opening flowers, the anthers generally emerge from the glumes and hang down quite intact for a time, the stigmas remaining quite uncovered with pollen. Then after a time which may extend occasionally even to five minutes or so, they burst and shed the pollen outside the glumes. In some cases, one or two of the anthers may remain held inside the glumes ; they may then burst inside and pollinate the stigmas.

As the temperature rises with the advance of the day, the anthers burst while emerging from the glumes or even while they are inside, thus covering the respective stigmas quite fully.

It may be supposed that, as a general rule, the stigma is receptive by the time the glumes open, because, leaving aside the earliest opening flowers, the stigmas in the glumes opening in our presence are more or less covered with pollen. This shows that the stigmas and pollen are both in a fit condition at the normal time of the opening of the flowers.

It has been observed in some cases that the two stigmas spread out so that they protrude beyond the margin of the flowering glume and pale, and when these close up, they are caught up between their overlapping edges. It is suspected that this may happen if for some reason or other the stigmas are not self pollinated. They can often be seen then as brownish specks on either side of the spikelets when the spikelets are mature. Such an exposed condition of the stigmas may occasionally be helpful in bringing about cross pollination either through wind or through insects. In connection with the possibility of insect agency, it has been noticed that Cantharid blister beetles and bees commonly visit the rice flowers during the hours of flowering.

In the period of flowering, especially of the late types, there is generally no rain ; but the wind is often strong, and it must be a powerful agent in bringing about cross-pollination at least in a few of the flowers in which the stigmas may remain exposed as stated above, especially if the crop is of a heterogeneous nature. In fact, when the anthers are bursting, the slightest jerk is enough to show tiny clouds of pollen grains wafted by the wind to the nearest panicle. A large number of blister beetles of two or three kinds are also seen busily engaged in feeding on the anthers, most of which are already quite or partially emptied of their pollen. The abdominal parts of these insects and their legs etc. are covered with hair to which the pollen is seen to adhere. Similarly, small bees and thrips are also occasionally seen to visit the rice flowers. So, all things taken together, with the exposed condition of the stigmas in certain cases, might easily explain the occasional cross-pollination [1] which takes place in rice. Besides we may also have to take into consideration (in some cases at least) the prepotency [2] of foreign pollen, even supposing that in many cases in which the stigmas remain exposed, self-pollination may have been effected.

The panicle. The panicle in the different strains of *Kolamba* rice shows considerable variation under the following heads :—(1) length, (2) number of branches, (3) total number of spikelets, (4) density, (5) sterility, (6) nature when ripe and (7) yield or weight of grain.

Length of panicle. It is usual to measure the length of the panicle from its lowest node which is generally hairy to the tip of the main axis. The length of the panicle in the different strains so measured varies on an average from 22 cm. to 29 cm. It may be said in general that in accordance with the nature and stature of the plant, such as short or tall, the panicle may be short or long. The branches of the panicle also may be short or long according as the panicle is short or long.

Number of Branches. The number of primary branches of the panicle varied in our cultures from 10 to 14·9. Curiously enough, long panicled types have pro-

[1] Hector G. P. Notes on pollination and cross pollination in the common rice plant, *Oryza sativa*. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. VI, No. 1. F. R. Parnell, G. N. Rangaswami Iyengar and K. Ramiah. The inheritance of characters in rice. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. V, No. 7.

[2] Darwin and modern science, by A. C. Seward.

portionately fewer branches, whereas the short panicled types have a comparatively larger number. Consequently, longer panicles are somewhat sparser in appearance, whereas the shorter ones are denser or more compact. But in this respect the total number of spikelets borne by the panicle or in fact by an individual branch is also greatly responsible, because both in the case of the number of branches and also in the case of the number of spikelets, the larger the number per unit length, the greater the compactness becomes evident.

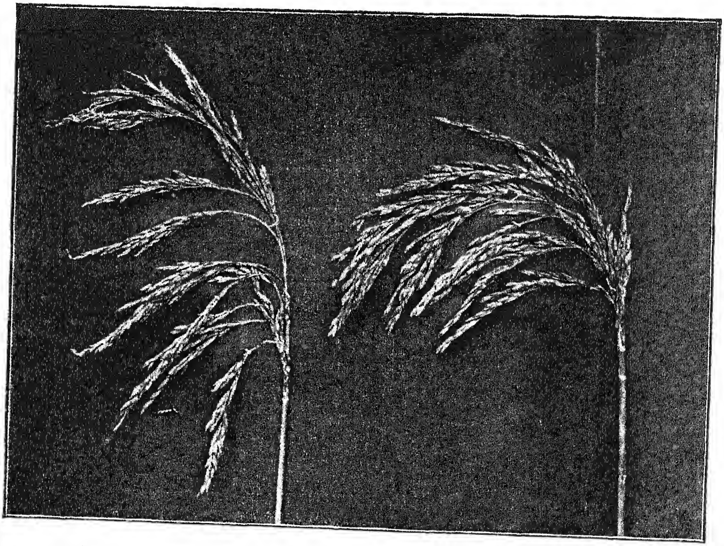
Occasionally the tips of the panicle branches show certain peculiarities, and although they are not of any great significance still they may be mentioned here in passing. (1) In that portion of a panicle where there is no sterility due to the presence of rudimentary spikelets, two spikelets at the end of a branch are placed much closer together than the lower ones, giving the appearance of what may be called tip clusters. This character is found commonly in many of the *Kolamba* types with compact heads. (2) In a few cases, the spikelets in a panicle and especially those near the tip of the branch are more or less strongly curved or hooked at the tip. It is suspected that this character has some relationship to sterility, since in a few perfectly sterile (Pl. IV, 1) plants which have been noticed such hooking at the tips of the spikelets was noticed to a marked degree.

Total number of spikelets. This has been ascertained by actually counting all the spikelets in the ripe main panicle including the fertile, the half developed and the unfilled or chaffy. The total number in the different strains varies from 253 to 575 on an average. Though it is desirable to have a very large number of spikelets in a panicle, still it has been found, as a general rule, that the large number of spikelets is associated with considerable sterility. It is also associated with fineness of grain and poor to medium tillering. So the grain yield of a panicle, or even the whole plant for that matter, is not necessarily proportionate to the number of spikelets borne by the panicle.

Density of the panicle. Strictly speaking, the density or compactness of the panicle depends on (1) the length of the panicle, (2) the number of branches borne on the main axis, (3) the length of the flower bearing part of the individual branch and (4) the total number of spikelets in the panicle. In other words, density is an expression of the combined result of the four factors mentioned above. This expression is, however, very difficult to arrive at except in a very laborious way in practice and therefore it was considered very desirable to get an expression of density by dividing the total number of spikelets in the panicle by the length of the panicle only. Measured in this somewhat arbitrary way, the density of the main panicle in the different strains was found to vary from 9·2 to 22·3. It may be pointed out here that the main panicle or the one borne by the mother culm in a plant being generally the largest of all, carries the largest number of spikelets and is also the densest and heaviest, those borne by the successive tillers being smaller,

Jacobson, H. O. Correlative characters of the rice plant. *Philippine Agri. Review*, Vol. IX, page 118.

PLATE III.



Showing on the left, Sterility at top of the panicle; on the right, no sterility at top of the panicle,

sparser and lighter in comparison. Some degree of positive correlation seems to exist between the density and sterility, so that the denser the panicle the more sterility it has.

Sterility in the panicle. Sterility or the habit of producing unproductive spikelets is a phenomenon of a rather common occurrence in some rice varieties and in *Kolamba* in particular. It may be inborn or incidental and due respectively to internal or external causes. As a result, there is either a complete lack of fertilisation or an interference with the further development of the ovule, the economic loss in either case being practically the same. Instances of the first kind can be seen in several types of the *Kolamba* rice in which a smaller or larger portion at the top of the panicle is occupied by rudimentary and undeveloped spikelets which are quite white and papery in appearance and do not produce any grains. These colourless or rudimentary spikelets can be seen only while the panicle has just emerged from the sheath or for three or four days after. But later on when the panicle ripens, they dry up and fall off. Similar rudimentary spikelets are also found sometimes at the base of the lower branches in certain types of *Kolamba*. A very similar result is often produced in fields which receive large quantities of manurial washings as near village sites. This kind of sterility is known as sponginess in Java. It is evident that in the case of such rudimentary spikelets both the pollen and the ovary are more or less aborted. Occasionally, certain plants are found in which there is absolutely no grain-formation. They remain green long after their brothers have dried up, and show complete lack of self fertilization in their panicles. The spikelets are nearly normal in form and texture though slightly reduced in size. This want of grain formation has been found to be due to the impotency of the anthers,[1] since the pollen grains which they contain are quite deflated and devoid of contents. In such plants occasionally a grain or two may be formed, but it is probably due to the cross pollination from normal plants. In a few cases, attempts had been made to cross such flowers artificially, but the attempts were not successful.

Instances of the second kind of sterility are those in which the panicles remain unfilled and feathery owing to the attack of stem borers or of sclerotial disease. In these cases, the supply of nutrition is cut off and the whole panicle dries up without producing well developed grains.

Occasionally only stray spikelets in a panicle which are quite normal in appearance remain undeveloped due probably to chance lack of fertilization or to unfavourable weather conditions interfering with the act of fertilization, such as heavy rain or very strong sun and winds during flowering. The first condition may either wash the pollen off or cause it to degenerate and the second may dry the pollen up before it is able to germinate on the stigma. It is suspected that, in some such

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[1] Bhide, R. K. A cause of sterility in rice flowers. *The Agricultural Journal of India*, Vol. XVII, p. 584 (1922).

cases also, this partial sterility may be due to the impotency of the anthers in some of the spikelets, but the matter needs further confirmation.

Regarding this sterility of the normal looking spikelets interspersed in the panicle just described, it was observed that in the F_2 generation of certain crosses, a few plants showed that the stamens from a good many spikelets emerged by the normal elongation or their filaments, but the anthers, though quite yellow and outwardly normal looking, did not burst. Most of them appeared to remain yellow and unburst till they dried up. The stigmas from such spikelets were generally uncovered with pollen. On opening such anthers under the dissecting microscope they looked somewhat moist and their contents did not separate into a floury dust. Thus even in this case, the failure seems to be due to the defective condition of the pollen in some spikelets. It could not have been due to want of sunshine, low temperature, etc., since all plants did not show it nor did several other strains show it. In all normal cases, the anthers generally burst while emerging, or just after emergence and assume a whitish colour on shedding their pollen.

In certain cases, some of the lower spikelets in a panicle contain only partially developed grains. This is due to the fact that they are fertilized latest of all, and hence, they cannot get enough time for grain development. Although there is no question here of sterility, still as this condition amounts in effect to practically the same thing, it has been thought desirable to include it here.

Sterility due to sponginess, that is to say, the rudimentary condition of the spikelets is generally associated with types having short compact panicles and short fine grain in *Kolamba* rice. The more compact the panicle the more sterility it has. In such a plant the main panicle again shows more sterility than the later formed panicles as they are smaller and less compact. This kind of sterility due to "sponginess" is rarely found in types which have long and sparse panicles and coarse grains.

Sterility or unproductiveness due to physical or physiological interference with fertilization or partial development of grains can however be found in both types.

In the plant to plant measurements it is difficult to assign exact numerical values to the kind of sterility which is due to sponginess or to the presence of rudimentary spikelets, since they soon fall off. Nothing can, therefore, be made out of such sterility beyond noting the degree of its extent. But it is possible to assign values to the other kind in which the unfilled spikelets can be counted. The percentage of such unfilled or half filled to the well filled spikelets varies from 11 to 42 per cent. in the different strains.

From the breeder's point of view, sterility or sponginess is a very undesirable character. It means so much loss of grain which should have been normally developed. It is, therefore, essential to try and avoid it as far as possible. Unfortunately, there seem to be no fine grained types of *Kolamba* rice which may be said to be absolutely free from sterility.

Dimensions of the spikelets. The average length and breadth of the spikelets in the different strains of *Kolamba* vary from 7·57 to 9·51 mm. and 2·15 to 2·60 mm,

respectively according to the fineness or coarseness of the spikelets. In this connection it may be noted that apart from the length of the spikelet within certain limits it is the thinness which determines its fineness.

The weight of the spikelets. In order to get an idea of the average weight of the spikelets in the various strains, the average number of spikelets required to weigh a gram was found out for the various strains. This number varies from 45·5 to 83 respectively according to the coarseness or fineness of the spikelets. The proportion of husk to clean rice in a given quantity of clean paddy is about 1 to 4.

The nature of the ripe panicle. The panicle, as it emerges from the sheath, is somewhat cylindrical and tapering at both ends. In the course of flowering, the individual branches separate more or less in the different strains and begin to spread away from the axis. As the grain development proceeds, the branches spread out and give the inflorescence the appearance of an open panicle. But when the ripening advances and the spikelets are heavy, the upper part of the panicle droops down in the form of a scythe with the branches closing upon it. In certain cases, the branches do not close on each other though the top portion may droop, and then the panicle looks partly bent down with the branches spread out. In yet another kind which is of rare occurrence, the branches droop down, but the top being comparatively light stands erect. On the whole, the appearance of the mature panicle is dependent on the following factors :—

(1) The length of the panicle.
(2) The number of branches in the panicle.
(3) The length of individual branches.
(4) The number of mature grains on a branch and their fineness or coarseness.
(5) Emptiness or otherwise of the branches at their base.

As a result of the combination of one or more of these factors, the panicles show several types, four of which may be chiefly mentioned.

No. 1. Long and sparse type. In this type the panicle is long, the branches are long and few, the number of grains is comparatively smaller and their size coarser. The panicle when ripe droops almost near the middle. Such are strains 79 and 121.

No. 2. Long and rather compact type. In this type the panicle is medium in length, the number of branches is greater than in type 1. The length of the branches is slightly reduced, the grain size is medium and the panicle when ripe droops a little above the middle. Such are strains 164 and 8.

No. 3. Short and compact type. In this type the panicle length is more reduced than in the above, the number of branches is larger as compared with the length of the panicle, the grains are more numerous and fine. The branches do not droop nor open much but remain somewhat closer together and the appearance of the panicle is compact. Such are strains 39, 35 and 32.

No. 4. Short open type. In this type the panicle is short, the number of branches is medium, the grain is rather coarse, and the branches are somewhat

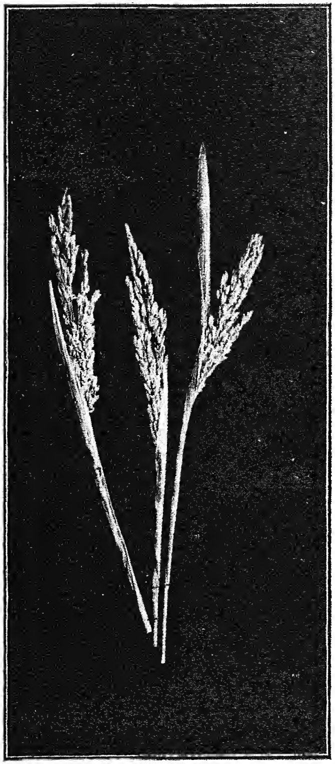
spreading. The ripe panicle consequently assumes an open appearance. Such is strain 153 or 42. The different types are illustrated in Plate IV, 2.

The yield of a panicle. It may be noted that plants with greater tillering have generally lighter panicles. Secondly, the yield of grain to be obtained from an average panicle depends on the average number of fertile grains borne on it, and the average weight of the individual grains. It has been already mentioned that those types in which the number of spikelets is very large are generally fine grained and show greater sterility on the whole. Consequently, the yield of grain to be obtained from a panicle of such a type is not necessarily very large in proportion to the number of spikelets. Because what is gained in number may not be much more than what is lost in weight. All the panicles again which a plant produces are not of equal size and weight. Efforts were made, therefore, to get an approximate idea of the average yield of a panicle. This was obtained by dividing the average yield per plant by the average number of bearing tillers. Thus the range of yield per average panicle in the different strains is 2·53 to 4·55 grams. When related to the size of the main panicle, the average panicle is found to be from 71 to 80 per cent. It may further be mentioned that it is not the length which so greatly falls in the successive panicles of a plant as the number of branches, the number of spikelets borne on them and the density.

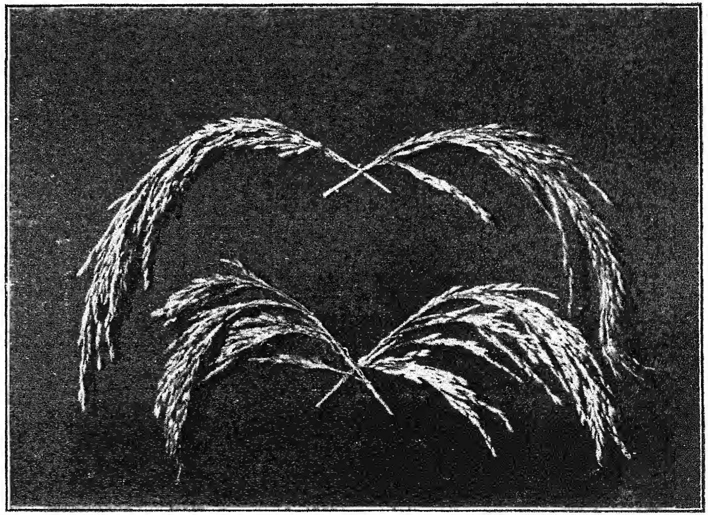
In the various pure strains of *Kolamba* rice which have been isolated by the authors, the correlation between the number of tillers and the yield of grain per average panicle has been found to be negative, though not by any means to the same extent. These results may be summarized in the following Table :—

Showing correlation between number of fertile tillers and weight of an average panicle.

Strain No.	Year	Mean number of fertile tillers	Mean weight of average panicle grams	Co-efficient of correlation between tillering and yield per average panicle	REMARKS
79	1923	3·08	3·84	—0·32±0·04	Coarse grained.
184	,,	3·56	2·53	—0·34±0·04	Medium grained.
153	,,	8·62	2·73	—0·19±0·04	Ditto.
164	,,	6·72	3·42	—0·05±0·04	Rather coarse grained.
32	,,	7·40	3·29	—0·15±0·04	Fine grained.
35	,,	6·25	4·07	—0·40±0·04	Ditto
42	1922	9·53	3·51	—0·24±0·04	Fairly fine grained.



1. Showing panicles which are completely sterile. Total sterility in *Kolamba* 34.



2. Showing four types of panicle. (1) Upper left—Long and sparse type; (2) Upper right—long and rather compact type; (3) Lower right—Short and compact type; (4) Lower left—Short open type.

Showing correlation between number of fertile tillers and weight of an average panicle.—contd.

Strain No.	Year	Mean number of fertile tillers	Mean weight of average panicle grams	Co-efficient of correlation between tillering and yield per average panicle	REMARKS
42	1923	9·48	3·17	—0·15±0·04	Fairly fine grained.
121	1922	7·74	4·55	—0·19±0·04	Coarse grained.
104	,,	11·66	2·94	—0·06±0·05	Medium to coarse grained.
104	1923	9·71	2·74	—0·04±0·04	Ditto.

From this it will be seen that within each pure strain there is in general a negative correlation between the number of fertile tillers and the yield of an average panicle. The amount of correlation appears to vary much. In some strains, as for instance Nos. 164 and 104, it hardly exists. In others, it is distinct, as for instance Nos. 35, 184 and 79.

As between different strains also the relationship between tillering capacity and the yield of the average panicle seems to be distinctly negative, as is seen in the following Table.

Showing correlation between mean tillering and mean weight of average panicle in different strains.

Mean weight of average panicle grams	Mean tillering per plant	Co-efficient of correlation	REMARKS
4·6	7·06	—0·39±0·09	Correlation appreciable.

The yield per plant. The yield per plant is of the utmost economic importance and depends, as will be seen from the above, on the combination of the yield of the average panicle and the effective tillering capacity of the plant. These characters are probably somewhat antagonistic in *Kolamba* rice. But a type with a fairly high tillering capacity and a moderately large and heavy panicle is likely to give the highest yield.

The relationship of tillering to yielding capacity per plant in a pure strain which is of a positive nature has been determined for a number of strains in 1923, a culture containing about 240 plants in each case forming the basis of the study.

The results are as follows :—

Showing correlation between tillering and yield per plant.

Strain No.	Mean number of fertile tillers	Mean yield of grain per plant grams	Co-efficient of correlation between tillering and yield per plant
79	4·1	11·7	0·71±0·02
184	3·6	8·9	0·80±0·001
153	8·6	23·4	0·67±0·02
164	6·7	23·0	0·72±0·02
32	7·4	24·1	0·75±0·02
35	7·2	25·2	072±0·02
42	9·5	29·8	0·64±0·02
121	7·7	35·9	....
104	9·7	26·5	0·84±0·02

It will be seen from these figures what a close relationship *within a strain* there is between number of tillers and the yield per plant. This is perhaps what might have been expected as the size of the earhead should vary little within a pure strain. Between different strains also the correlation is close, though not always so. The following tables are enough to show clearly that among strains of *Kolamba* rice, at any rate, yield is determined more by the number of fertile tillers than by any other factor, except perhaps the height of the plant :—

Correlation between tillering and yield per plant in different strains in different years.

Strain	Mean No. of fertile tillers	Mean yield per plant Grams	Co-efficient of correlation	Remarks
Reserve Kolamba strains 1923.	5·30	13·93	0·38±·05	The strains were widely different in period of flowering, grain size, No. of grains per panicle, weight of panicle, and yield per plant. The total observations were 138.
New panicle series, 1924	5·39	14·97	0·67±·02	The strains were more alike. These were 180 and 125 observations respectively.
New panicle series, 1925	6·21	18·81	0·64±·03	
Bulk Selection series, 1925.	5·64	16·42	0·62±·04	The strains were not so nearly alike as above. 87 observations.
Intensive cultures of different years.	8·10	27·15	0·77±·04	The strains were different from each other ·39 observations.

In almost all these cases the correlation is close.

Correlation between mean height of plant and mean yield per plant in the intensive cultures.

Strain	Mean height cm.	Mean yield per plant Grams	Co-efficient of correlation	REMARKS
Intensive cultures of different years.	142·18	27·08	0·47 ± ·08	39 observations. Correlation fairly close.

Correlation between the height and yield per plant in two strains in 1925.

Strain	Height in cm.	Yield per plant in grams	Co-efficient of correlation	REMARKS
42	156·7	36·00	0·54 ± 0·04	Correlation fairly close.
241	143·8	22·02	0·43 ± 0·05	

While dealing with these correlations, it will be interesting to indicate some others which have been investigated in 1921, 1922 and 1923 *within two of the pure strains isolated, viz.*, Nos. 79 and 42, the former an early and coarse grained type with low yield, and the latter a late type with finer grain and high yield.

The results are as follows :—

I. Correlation between tillering and the length of the main panicle.

Strain No.	Mean No. of tillers	Mean length of panicle cm.	Co-efficient of correlation between tillering and length of panicle	REMARKS
79 (1921)	8·5	26·7	0·11 ± 0·04	Correlation slight.
79 (1922)	5·0	27·5	0·11 ± 0·04	
42 (1922)	10·0	24·8	0·22 ± 0·04	Correlation rather appreciable.

II. Correlation between tillering and number of spikelets in the main panicle.

Strain	Mean No. of tillers	Mean of No. of spikelets	Co-efficient of correlation between tillering and spikelets	REMARKS
79 (1922)	6·0	274·0	0·35±·04	Correlation appreciable.
42 (1922)	10·0	419·2	0·07±·04	Correlation negligible.

III. Correlation between tillering and number of branches in the main panicle.

Strain	Mean No. of tillers	Mean No. of branches	Co-efficient of correlation between tillering and spikelets	REMARKS
42 (1922)	10·0	12·3	0·17±·04	Correlation slight.

IV. Correlation between number of branches and number of spikelets in the main panicle.

Strain	Mean No. of branches	Mean No. of spikelets	Co-efficient of correlation between branches and spikelets	REMARKS
42 (1922)	12·31	419·24	0·39±·03	Correlation appreciable.

Correlation between the length of the main panicle and the height of the plant in Strain No. 42 in 1922.

Mean length of panicle in cm.	Mean height of plant in cm.	Co-efficient of correlation	REMARKS
24·83	133·71	0·21±0·03	Correlation rather appreciable.

The following correlations were also worked out in the different strains in different years :—

I. Correlation between density and number of sterile spikelets in the main panicle in the different strains in different years.

Cultures	Mean density	Mean No. of sterile spikelets	Co-efficient of correlation	Remarks
Intensive cultures of different years.	16·18	88·60	0·63±0·07	33 observations. Correlation close.

II. Correlation between density and sterility percentage in different strains in different years.

Cultures	Mean density	Mean sterility percentage	Co-efficient of correlation	Remarks
Intensive cultures of different years.	16·18	19·70	0·29±0·10	33 observations. Correlation appreciable.

III. Correlation between number of grains per gram and sterility percentage in different strains in different years.

Cultures	Mean No. of grains per gram	Mean sterility percentage	Co-efficient of correlation	Remarks
Intensive cultures of different years.	69·22	19·70	0·16±0·11	32 observations. Correlation slight.

Thus it will be seen from the above results that there is a close correlation between density and number of sterile spikelets, and an appreciable one between density and sterility percentage. There is also appreciable correlation between number of branches of the panicle and number of spikelets and between tillering and number of spikelets in the panicle in strain No. 79, though the same in strain No. 42 is negligible. The correlation between length of the panicle and height may be said to be rather appreciable in the case of strain No. 42, but the other correlations worked out seem to be slight or negligible.

Returning to the consideration of the yield per plant, it may be stated that in the very early strains this is generally low, presumably owing to the short period of growth. Further, these very early strains have all a low tillering capacity and

their panicles also are small. Although the grains in these strains may be coarse, their individual weight is not large enough to make up the shortage due to low tillering and the small number of grains per panicle. The yield per plant in the late strains is generally more than in the early strains as will be seen from the following Table :—

Showing the comparative yields per plant in the early and late strains in the year 1923

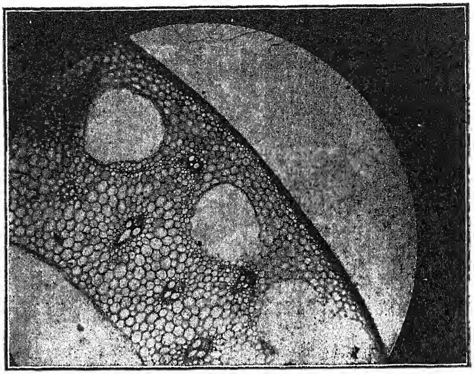
Nature of strain	Strains Nos.	Mean tillering per plant	Mean yield per plant	REMARKS
			grams	
Very early	No. 79	4·1	11·7	Coarse grained.
Very early	No. 184	3·6	8·9	Medium grained.
Intermediate . . .	No. 153	8·6	23·4	Medium grained.
Intermediate . . .	No. 164	6·7	23·0	Rather coarse grained,
Late	No. 32	7·4	24·1	Fine grained.
Late	No. 35	7·2	25·2	Fine grained.
Late	No. 42	9·5	29·8	Fairly fine grained.
Late	No. 121	7·7	35·9	Coarse grained.
Very late	No. 104	9·7	26·5	Med. to coarse grained.

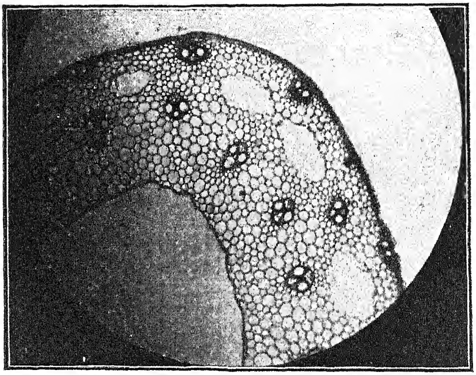
So far only the yield of grain has been considered, but the straw is of considerable importance also as it serves as fodder in the tract. The following are the comparative figures of grain and straw yields in the extensive cultures grown in a plot of one-fortieth of an acre each in the year 1924.

Strain No.	Grain weight in lb. from number of bunches of equal size			Straw weight in lb. from number of bunches			RATIO OF GRAIN TO STRAW	
	lb.	oz.	Bunches	lb.	oz.	Bunches	Grain	Straw
153 . .	69	00	1,629	72	00	1,629	1·000 :	1·044
164 . .	62	08	1,787	72	04	1,787	1·000 :	1·156
32 . .	80	10	1,474	83	00	1,474	1·000 :	1·029
35 . .	89	04	1,734	92	12	1,734	1·000 :	1·039
39 . .	76	08	1,661	83	12	1,661	1·000 :	1·094
42 . .	84	12*	1,248	77	04	1,248	1·095 :	1·000
223 . .	77	14	1,468	73	06	1,468	1·060 :	1·000
104 . .	77	08	1,307	107	06	1,307	1·000 :	1·380

* The low yield of strain No. 42 here is due to thin planting as will be seen from the number of bunches.

PLATE V.





A.—Transverse section of stem of a standing strain. Behind the air cavities lined by single layers of larger cells can be seen bands of sclerenchymatous tissue. These are conspicuous by the very small size of their cells and greater thickness of their walls. These bands are absent in B, the transverse section of a lodging strain.

The above table shows that Nos. 42 and 223 give more grain than straw, while the others give more straw than grain.

Strength of straw. This is rather an important character in determining the utility of a strain of rice. On it depends to a certain extent whether a strain can maintain an erect position or is likely to lodge in the field at maturity. Such lodging at maturity entails not only some loss of grain, but also a reduction in its quality, especially if the fields are very wet. The actual standing or lodging of any strain is influenced by external conditions such as the high fertility of the field and the weather at the time of maturity. If the fields are very richly manured, the stem tissues become softer and more supple and the plants cannot maintain an erect position. They are easily swayed by the wind, the stems spread and bend outwards and the crop lodges. Stormy weather at maturity generally causes the plants to lodge even though they may be strong in straw. But if we leave out of consideration these abnormal external conditions, then such strains as have a short stature, an erect habit of growth, and a thick culm with a certain amount of mechanical tissue in the stem structure which gives the stems more rigidity, are more likely to stand. Plate V, A shows the stem structure which is generally found in strains which are likely to maintain an erect position at maturity. In them there is a thicker band of sclerenchymatous tissue at the periphery of the stem than in the lodging strains, the fibro-vascular bundles are more numerous, and there are particularly a few layers of small sized sclerenchymatous cells behind the air cavities which are generally found in the hollow rice stem owing to its aquatic habit. These layers of small sclerenchymatous cells are more or less continuous with the sclerenchymatous sheaths of the fibro-vascular bundles lying on either side of the air cavities and form arches of mechanical tissue behind them. They are generally absent in the lodging strains (Pl. V, B). In order to see them, it is necessary to examine sections of stems of the various strains taken at a particular point in the first internode or a little below the second node above the ground when the strains are nearing maturity. Associated with the strength of straw is very often found the erectness of the flag which can be noticed even after the crop has begun to ripen.

Susceptibility to the attack of the stem borer. Some strains seem to be particularly liable to the attack of the rice stem borer, *Schoenobius bipunctifer*, so that in such strains we generally find more plants with white unfilled and feathery earheads than in others. Consequently, this character is very undesirable. It is probably due to the tendency of the strain to have very soft stem tissues, as even in the other strains the borer trouble can be noticed if they are grown in very rich fields or under the shade of trees where softness of tissues is particularly encouraged.

Liability to the green or false smut of rice.*—Certain strains especially those which have a short and compact panicle seem to be more liable to this smut than

* Butler, E. J. Fungi and Disease in Plants, page 228.

others in certain seasons, and though the damage caused by it is not very appreciable, still there is no doubt that it is not a very desirable character. The belief of the cultivators, however, is that this disease appears more particularly in a good crop season.

The habit of shedding the grains at maturity. It is true that this habit is never so marked in *Kolamba* rice as in the "Gonag "[1] of the Dharwar-Belgaum Mallad or in wild rice generally, in which the grains fall away as soon as they are mature. In the case of some *Kolamba* strains, a few of the topmost grains only shed if the crop is a little over ripe. It is found that some long and slender grained types show this habit to a slightly greater extent than those with shorter and thicker grains, and consequently the harvesting of such types has to be done before the crop is dead ripe.

IV. Description of selected strains of Kolamba rice.

It is now proposed to give a short description of the eight pure strains of *Kolamba* rice, grown from selfed seed for several generations and which have maintained their uniformity in the characters studied. They do not necessarily represent the whole of the variety; for all were originally selected among others for some valuable character such as high yield, stiff straw, early ripening, etc., and represent the best among the numerous types originally obtained. Of them, one is a very early type, two are early, four belong to the main crop of late types, and one is a very late type.

Strain No. 79. This is the earliest ripening strain found in the mixed *Kolamba* rice seeds obtained from the greater part of the area. It has the fewest tillers and least number of branches in the panicle. The amount of sterility is small, and the density of the panicle is low. The yield per plant is low, and the grain is coarse.

This strain is valuable because of its very short period for ripening. It requires about 110 to 115 days from sowing to harvesting. It is, hence, suitable for lands where the water-supply does not last long owing to their high lying character. Though very coarse as *Kolamba* rice, it is finer than the available varieties, other than *Kolamba*, for such soils. It is not superior to such varieties in point of yield, but owing to its finer grain it brings in usually an increased return of about Rs. 10 per acre. The colour of husk is deep brownish yellow and the kernel is also slightly tinged with amber. But on polishing, it becomes quite white and flinty.

With a normal sowing date about June 6th, the date of flowering (as taken from 120 to 250 plants) has varied from August 29th (1921) to September 5th to 7th (1923) or from 84 to 92 days. As has already been stated, the strain ripens in 110 to 115 days, that is to say, it needs about 26 to 31 days from flowering to ripening.

The average number of fertile tillers per plant when grown under the conditions of study previously described varied from an 8·4 * in 1921, to 5·0 in 1922,

[1] Salimath Gonag: a weed in drilled paddy, *Bombay Department of Agriculture, Bulletin* No. 107 of 1921.

* The spacing in the field in 1921 was wider than in succeeding years.

and to 4·6 in 1923. This difference is not purely seasonal, but shows the extent of variation that may be expected, under varying conditinos of spacing. The general average is just 6·0 tillers per plant. Of this total No. of tillers 7·8, 4·5 and 4·1 have yielded earheads in the three years studied. The proportion has thus been 93 per cent., 90 per cent. and 89 per cent in the three seasons, or a general average of 91 per cent.

The height of the plant has varied from an average of 118½ cm. in 1923 to 133½ cm. in 1921, giving an average height at Karjat of 125 cm. The panicle length has been very constant only varying from 26·3 to 27·5 cm. These figures have, of course, nothing absolute about them, and are only given to enable comparisons to be made with other strains grown under similar conditions.

Details as to the characters of the panicle on the average, are shown in the following Table :—

Main panicle characters.

Year	No. of branches	Total No. of spikelets	Density of panicle	No. of sterile spikelets	Yield in grams	REMARKS.
1921 . .	10·1	252	9·3	32·9	4·8	Wider spacing.
1922 . .	10·2	247	10·0	65·3	4·2	
1923 . .	9·2	251	9·4	47·7	4·0	
1924 . .	9·7	241	8·4	31·3	3·9	
General average	9·8	255	9·3	44·3	4·2	

The most interesting of these figures is that showing the variation in the proportion of sterile spikelets from season to season on the main panicle. These sterile spikelets amount to 13 per cent. in 1921 and 1924 ; 24 per cent in 1922 ; and 19 per cent. in 1923 ; and indicate the extent to which variations in yield, even in a pure line, may be caused by seasonal conditions.

The above figures deal with the main panicle ; the following show the yields from the main and average panicle, and from the whole plant :—

Year	Yield of main panicle (average)	Yield of average panicle	Yield of whole plant
	gram	gram	gram
1921	4·8	3·2	25·8
1922	4·2	3·4	14·9
1923	4·0	2·8	11·7
1924	3·9	2·5	16·7
General average . .	4·2	3·0	17·3

The character of the spikelets themselves is shown by the following determinations of average length and breadth, while the size is clearly shown by the number of spikelets per gram :—

Year	Average length of spikelet mm.	Average breadth of spikelet mm.	No. of spikelets per gram
1921	9·3	2·40	51
1922	9·3	2·40	49
1923	9·3	2·50	52
1924	9·4	2·40	54
General average . . .	9·3	2·42	51

Strain No. 164.

This is a type, which while ripening later than No. 79, is yet a rather early strain. It has the longest grain (spikelet) among all the selections made in *Kolamba* rice. It is rather strong in the straw, and is suitable for high lands which retain water a little longer than those on which No. 79 would be grown. It is distinctly finer or more slender than that last described, but among *Kolamba* rices it would be classed as rather coarse. It would bring about Rs. 12 to Rs. 15 per acre, normally more than the coarse non-*Kolamba* rices suitable for similar lands. The colour of the husk is a light brownish yellow, and that of the kernel a very light amber. The grains are white and flinty when polished.

With a normal sowing date about June 6th, the date of flowering has varied from September 25th to 28th and the length of time from sowing to flowering from 111 to 114 days. The strain ripens in 135 to 140 days, and then it needs about 24 to 26 days from flowering to ripening.

The average number of fertile tillers per plant when grown under the conditions of growth previously described varied from an average of 7·8 in 1923 to 10·5 in 1922. The general average is 9·2 per plant. Of this total number of tillers 6·7 and 8·1 respectively yielded fertile earheads in the two years of study. The proportion has thus been 86 and 88 per cent. respectively in the two years, or a general average of 87 per cent.

The height of the plant has varied from an average of 140 centimetres in 1923 to 142 cm. in 1922. The panicle length is a very constant feature, only varying

from 27·2 to 27·4 cm. on the average based on a study of main panicle only, as shown in the following Table :—

Main panicle characters.

Year	No. of branches	Total No. of spikelets	Density of panicle	No. of sterile spikelets	Yield in grams
1922	13·4	349	12·7	70·8	5·3
1923	12·7	349	12·9	50·5	5·0
1924	13·6	369	13·1	66·0	5·3
General average	13·2	356	12·9	62·4	5·2

The sterile spikelets amounted to 20·3 per cent. of the whole number on the panicle in 1922, while in 1923 and 1924 the corresponding figures were 14·5 and 18 per cent. respectively. It will be seen that in two cases the proportion of sterility is less than in strain No. 79, and the change caused by the differences in season is in the same direction in the two strains.

The above figures deal with the main panicle. The following show the yields from the main and average panicle and from the whole plant :—

Year	Yield of main panicle	Yield of average panicle	Yield of whole plant
	grams	grams	grams
1922	5·3	3·8	30·9
1923	5·0	3·4	23·0
1924	5·3	3·5	25·1
General average	5·2	3·6	26·3

The character of the spikelets themselves is shown by the following determinations of average length and breadth, while the size is clearly shown by the number of spikelets per gram :—

Year	Average length of spikelet mm.	Average breadth of spikelet mm.	No. of spikelets per gram
1922	9·3	2·30	54
1923	9·4	2·40	59
1924	9·4	2·40	56
General average	9·36	2·36	56

Strain No. 153.

Strain No. 153 is one which ripens almost at the same time as that last described, and so may be classed as a rather early strain. It has the shortest panicle length among all the selections made of *Kolamba* rice. It yields well, and is finer and shorter in grain size than No. 164. It is valuable for the same type of land as No. 164, but has a weaker straw than the latter. Owing to its finer grain it brings a higher price than No. 164. The colour and behaviour of the spikelets and grains are very similar to that last described.

With a normal sowing date about June 6th to 10th, the date of flowering has varied from September 25th to 29th ; and the length of time required for flowering is from 111 to 115 days. The strain ripens in 135 to 140 days, and thus it needs from 24 to 25 days from flowering to ripening.

The average number of fertile tillers per plant, when grown under the conditions previously described, varied from an average of 8·7 in 1923 to 11·2 in 1922. The general average is 9·9 per plant. Of the total number of tillers, 8·6 and 10·2 respectively yielded fertile earheads, in the two years of study. The proportion of tillers which are fertile has thus been nearly 99 per cent. in 1923, and 91 per cent. in 1922, or a general average of 95 per cent.

The height of the plant has varied from an average of 137 cm. to 142 cm. The panicle length, which is very short as already noted, varies from an average of 20·6 cm. to 22·0 cm. in the two years under study.

Details as to the characters of the panicle, based on a study of the main panicle only, are as follows :—

Main panicle characters.

Year	No. of branches	Total No. of spikelets	Density of panicle	No. of sterile spikelets	Yield in grams
1922	12·9	371	17·9	128·3	3·7
1923	12·0	391	17·7	86·4	4·2
1924	11·0	345	17·1	80·1	3·7
General average	12·0	369	17·6	98·3	3·9

It will be seen that the proportion of sterile spikelets on the main panicle has varied from nearly 38 per cent. in 1922 to about 22 to 23 per cent. in 1923 and 1924. As with other strains the sterility was much less in 1923 than in 1922, but in both years it was considerably greater with this than with the strains previously described.

The above figures deal with the main panicle. The following show the yields from the main and average panicle and from the whole plant :—

Year	Yield of main panicle	Yield of average panicle	Yield of whole plant
	gram	gram	gram
1922	3·7	3·0	30·5
1923	4·2	2·7	23·4
1924	3·7	2·6	22·4
General average . . .	3·9	2·8	25·4

The character of the spikelets themselves is shown by the following determination of average length and breadth, while the size is shown by the number of spikelets per gram.

Year	Average length of spikelet	Average breadth of spikelet	Number of spikelets per gram
	mm.	mm.	
1922	8·2	2·30	66
1923	8·2	2·40	73
1924	8·3	2·30	71
General average . . .	8·23	2·33	70

This shows how much smaller is the grain than in the strains previously considered.

Strain No. 32.

Strain No. 32 is later than those previously considered and belongs to the *late* types. It is one of the selections which have the finest and hence the lightest grain, but it yields well. It is specially valuable as combining fairly good yield and fine quality of grain which fetches a good price in the market. The colour of the husk is pale yellowish brown, and that of the kernel is white. The grain on polishing is quite white and flinty.

With a normal sowing date about 6th to 10th June, the date of flowering has varied from October 4th to 8th ; and the length of time from sowing to flowering from 118 to 122 days. The strain ripens in 145 to 150 days, and thus needs from 25 to 26 days from flowering to ripening.

The average number of fertile tillers per plant when grown under the condition previously described varied from an average of 8·8 in 1923 and 9·7 in 1922 to 14·9 in 1921.* The general average is 11·1 per plant. Of this total number of tillers, 8·4, 9·0 and 14·0 yielded fertile earheads in 1923, 1922 and 1921 respectively. The proportion of tillers which are fertile has thus been 95·5 per cent. in 1923, 92·8 per cent. in 1922, and 94·6 per cent. in 1921, on the general average of 94·3 per cent.

The height of the plant has varied from an average of 137·31 cm. in 1923 and 134·6 cm. in 1922 to 151 cm. in 1921; the average height in three different years at Karjat being 141 cm. The panicle length is about average for *Kolamba* rices, and has varied from 22·9 to 25·1 cm. in the four years under study.

Details as to the characters of the panicle, based on a study of the main panicle only, are as follows :—

Main panicle characters.

Year	No. of branches	Total No. of spikelets	Density of panicle	No. of sterile spikelets	Yield in grams
1921	12·5	436	17·9	91·5	4·4
1922	13·3	469	18·7	110·9	4·6
1923	13·0	461	20·0	119·3	4·2
1924	12·8	428	16·5	106·3	4·2
General average	12·9	448	18·3	107·0	4·4

It will be seen that the proportion of sterile spikelets on the main panicle has varied between nearly 30 per cent. in 1921, nearly 24 per cent. in 1922, and 25 to 26 per cent. in 1923 and 1924. Unlike the earlier strains, the percentage of sterility was not lower in 1923 than in the previous year.

The above figures deal with the main panicle. The following show the yields from the main and average panicle and from the whole plant.

Year	Yield of main panicle	Yield of average panicle	Yield of whole plant	REMARKS
	grm.	grm.	grm.	
1921	4·4	3·1	43·0†	†The number of plants was only 88 or comparatively small and the edge effect considerable.
1922	4·6	3·4	30·6	
1923	4·2	3·3	24·1	
1924	4·2	3·0	28·5	
General average	4·4	3·2	31·5	

* The spacing in the field in 1921 was wider than in succeeding years.

The character of the spikelets themselves is shown by the following determination of average length and breadth, while the size is shown by the number of spikelets per gram.

Year	Average length of spikelet	Average breadth of spikelet	Number of spikelets per gram.
	mm.	mm.	
1921	7·8	2·20	77
1922	7·9	2·20	76
1923	7·8	2·30	81
1924	7·8	2·20	75
General average	7·82	2·22	77

The fineness of the grain even as compared with the fairly fine type No. 153 is well illustrated by these figures.

Strain No. 35.

This strain is similar to that last described as regards time required to produce flowers and to mature. It represents absolutely the finest type in the selections made, and is curious moreover as having the largest number of branches and the largest number of spikelets in the main panicle. But it also shows the highest sterility. The panicle is the densest among the strains isolated. It is a useful strain, as combining a fairly good yield and fine quality of grain. The colour of the husk is light and the grain is white and flinty and polishes well. It seems very liable to the disease known as false smut.

With a normal sowing date about June 6th, the date of flowering has varied from October 4th to 8th; and the length of time from sowing to flowering from 120 to 124 days. The strain ripens in 145 to 150 days, and thus needs from 25 to 26 days from flowering to ripening.

The average number of fertile tillers per plant when grown under the conditions previously described varied from 7·7 in 1922 and 1923 to 13·1 in 1921.* The general average is 9·5 per plant. Of this total number of tillers 7·2, 7·4 and 12·5 yielded fertile earheads in 1923, 1922, and 1921 respectively. The proportion of tillers which are fertile has thus been $93\frac{1}{2}$ per cent. in 1923, 96 per cent. in 1922, and $95\frac{1}{2}$ per cent. in 1921 on an average of 95 per cent.

The height of the plant has varied from 136 cm. to 148 cm., the average of three years at Karjat being 142 cm. The panicle length has lain between 23·6 cm. and

* The spacing in the field in 1921 was wider than in succeeding years.

25·6 cm. with the average of 24·6 cm., or again about the average for *Kolamba* rices.

Details as to the characters of the panicle, based on a study of the main panicle only, are as follows :—

Main panicle characters.

Year	No. of branches	Total No. of spikelets	Density of panicle	No. of sterile spikelets	Yield in grams	REMARKS
1921 . . .	16·0	588	23·8	140	5·8	Plants few and edge effect considerable.
1922 . . .	16·3	575	23·4	148	5·4	
1923 . . .	15·2	510	21·6	110	4·9	
1924 . . .	14·0	484	18·5	101	4·9	
General average .	15·4	539	21·8	125	5·2	

The proportion of sterile spikelets is high, and has varied from 21·6 per cent. in 1923 to nearly 24 and 25 per cent. respectively in 1921 and 1922. In this strain there was a lower percentage in 1923, as with the earlier strains previously described.

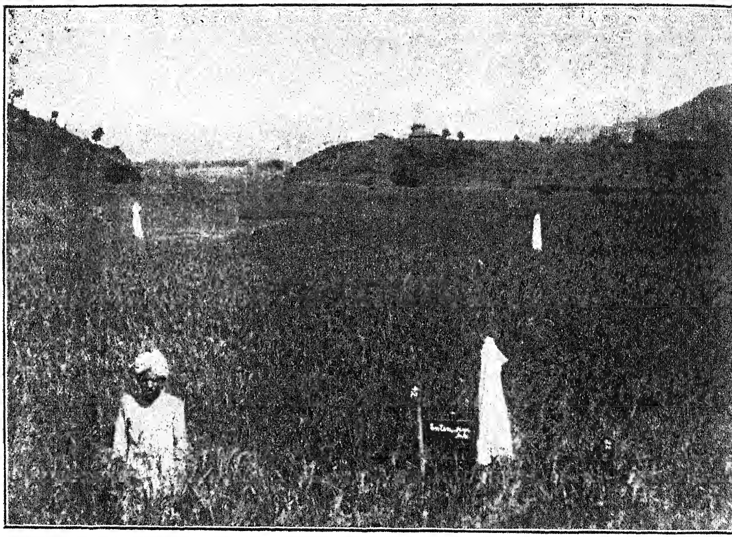
The above figures deal with the main panicle ; the following show the yields from the main and *average* panicle and from the whole plant.

Year	Yield of main panicle	Yield of average panicle	Yield of whole plant	REMARKS
	grm.	grm.	grm.	
1921	5·8	4·1	51·3*	*The number of plants was only 67 or comparatively small and the edge effect considerable.
1922	5·4	3·9	29·5	
1923	4·9	3·7	25·2	
1924	4·9	3·5	31·1	
General average . .	5·2	3·8	34·3	

The character of the spikelets themselves is shown by the following determination of average length and breadth, while the size is shown by the number of spikelets per gram.

Year	Average length of spikelet	Average breadth of spikelet	Number of spikelets per gram
1921	7·6	2·2	74
1922	7·6	2·1	79
1923	7·5	2·3	83
1924	..	..	78
General average	7·6	2·2	79

PLATE VI.



Showing extensive cultures of strain No. 42 on the left and of strain No. 32 on the right.

These figures show that in fineness this strain is as good as or perhaps a little superior to No. 32, described above.

Strain No. 42.

This strain is of peculiar interest, as it is the one which has proved to be of the greatest practical importance. It is now grown annually on many thousand acres, and the demand for the seed is now keen. Its chief characteristics are its good tillering and heavy yield; while its grain is *fairly* fine. It has an erect habit of growth, an open panicle, with slight sterility at the top. It has to be noted in connection with this strain that it can be grown in fields which receive large quantities of nitrogenous manures without the fear of running to leaf, at the cost of grain. Consequently, it will bear much higher manuring than most of the other types.

With a normal sowing date about June 6th, the date of flowering has varied from October 4th to 8th, and the length of time from sowing to flowering from 120 to 124 days. The strain ripens in 145 to 150 days, and thus needs from 25 to 26 days from flowering to ripening.

The average number of fertile tillers per plant when grown under the conditions previously described varied from 9·8 in 1923 to 11·6 in 1921. The general average is 10·4 per plant. Of the number of tillers, 95 per cent. bore fertile earheads in 1921, 96 per cent. in 1922, and 97 per cent. in 1923. This gives an average of 96 per cent.

The height of the plant has varied from 134 cm. to 138 cm., the average of the three years at Karjat being 137 cm. The panicle length has lain between 24·2 cm. and 24·8 cm. with an average of 24·5 cm.

Details as to the characters of the panicle, based on a study of the main panicle only, are as follows :—

Main panicle characters.

Year	No. of branches	Total No. of spikelets	Density of panicle	No. of sterile spikelets	Yield in grams
1921	11·2	372	15·1	57	4·6
1922	12·3	419	16·8	90	4·9
1923	12·8	407	16·8	70	4·8
1924	12·3	378	14·5	68	4·5
General average	12·1	394	15·8	71	4·7

The proportion of sterile spikelets has varied from 15½ per cent. in 1921 to 21½ per cent. in 1922, and to 17 and 18 per cent. in 1923 and 1924 respectively. The average for the four years is 18 per cent.

The above figures deal with the main panicle; the following show the *yields* from the main and *average* panicle, and from the whole plant.

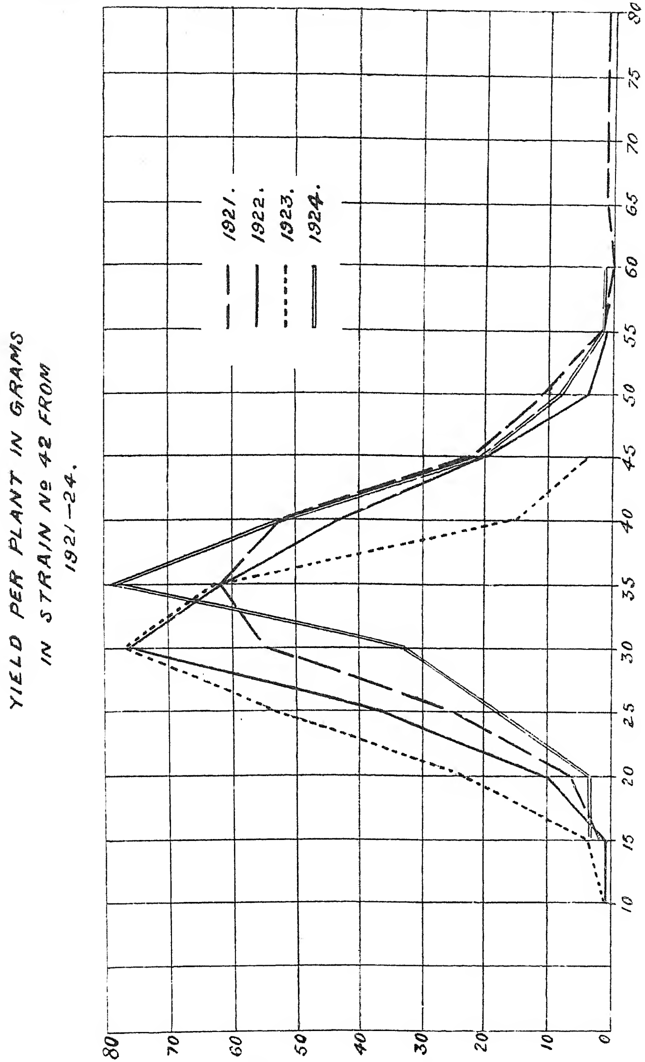
Year	Yield of main panicle	Yield of average panicle	Yield of whole plant*	Remarks
	grm.	grm.	grm.	*See Plate VII.
1921	4·6	3·2	35·7	
1922	4·9	3·5	33·3	
1923	4·8	3·2	29·7	This was a poor season.
1924	4·5	3·4	35·9	
General average . .	4·7	3·3	33·6	

The character of the spikelets themselves is shown by the following determinations of their average length and breadth, while the size is shown by the number of spikelets per gram.

Year	Average length of spikelet	Average breadth of spikelet	No. of spikelets per gram
	mm.	mm.	
1921 . . .	8·2	2·3	67
1922	8·1	2·3	68
1923	8·1	2·3	70
1924	..	..	67
General average . . .	8·1	2·3	68

Strain No. 121.

This strain, though it would still be classified as a late or 'main crop' strain, yet it is about ten days later in maturing than the last three described. It is the tallest of all the selections, has the longest and heaviest panicle and the thickest grains. Unfortunately, though it has been under cultivation since 1920, yet close detailed plant to plant observations were only made in 1922, and hence it is not


YIELD PER PLANT IN GRAMS
IN STRAIN No 42 FROM
1921–24.
1921.
1922.
1923.
1924.
80 70 60 50 40 30 20 10 0
10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

possible to compare its characters with complete confidence with the average figures for the other strains. It has only theoretical interest as, though it yields very highly, the grain is too coarse for the market expectation of a *Kolamba* rice.

With June 13 as the sowing date, the date of flowering in 1922 was October 9th to 10th, giving a period of growth to flowering of 118 to 119 days. The strain ripens in 150 to 155 days and thus needs about 30 days or so from flowering to ripening.

The average number of fertile tillers per plant when grown under the conditions previously described was 9·1 per plant, and the fertile earheads numbered 7·7 per plant. This gives a proportion of fertile earheads to total tillers of 85 per cent.

The height of the plant in 1922 under the Karjat conditions was 167 cm. on the average, and the panicle length reached 30·1 cm. Details as to the characters of the panicle, based on a study of the main panicle only, are as follows :—

Main panicle characters. Year 1922.

Number of branches	14·9
Total No. of spikelets	387
Density of panicle	12·7
No. of sterile spikelets	92
Yield of grain	5·8 grams.

The proportion of the sterile spikelets was nearly 24 per cent. in 1922.

The above figures deal with the main panicle ; the following show the yields from the main and average panicle, and from the whole plant in 1922.

Year 1922.

Yield of main panicle	5·8 grams.
Yield of average panicle	4·5 „
Yield of whole plant	35·9 „

The character of the spikelets themselves is shown by the following determinations :—

Year 1922.

Average length of spikelet	8·8 mm
Average breadth of spikelet	2·6 mm.
Number of spikelets per gram	51

These figures illustrate the relative coarseness of the grain in this strain.

Strain No. 104.

Strain No. 104 is the latest of all the selections made and requires about 160 to 165 days from sowing to ripening. It is hence only valuable for low-lying land which retains water until very late in the season. It has a very large number of tillers, the largest in the series,—but on the other hand it has the smallest number

of spikelets on the main panicle which is loose in formation. The sterility is very low. The grain is somewhat coarse, and the straw is strong.

With a normal sowing date about June 6th, the date of flowering has varied from October 17th to 19th, giving a period of growth to flowering of 130 to 135 days. The strain ripens in about 160 to 165 days, so that it requires about 30 days from flowering to ripening.

The average number of fertile tillers per plant, when grown under the conditions previously described, was 10·6 in 1923, and 14·1 in 1922. The general average is thus 12·3 per plant. Of this No. of tillers 9·7 in 1923 and 11·7 in 1922 bore fertile earheads, or a proportion of 91·5 per cent. in 1923 and 83 per cent in 1922. This gives an average of just over 87 per cent.

The height of the plant has varied from 131 cm. to 134 cm. That is to say, its average (132½ cm.) is just about that of the variety. The panicle length has lain between 24·3 and 24·8 cm. with an average at 24·5 cm.

Details as to the character of the panicles, based on a study of the main panicle, are as follows :—

Main panicle characters.

Year	No. of branches	Total No. of spikelets	Density of panicle	No. of sterile spikelets	Yield in grams
1922	15·7	241	9·7	26·2	3·7
1923	11·9	239	9·9	30·5	3·6
1924	12·8	264	10·5	26·7	4·5
General average	13·5	248	10·0	27·8	3·9

The proportion of sterile spikelets has varied from 10·8 per cent. in 1922 to 12·7 per cent. in 1923, and to 10 per cent. in 1924, or a general average of 11·2 per cent. This, it will be noticed, is very low for *Kolamba* rice.

The above figures deal with the main panicle; the following show the yields from the main and average panicle, and from the whole plant.

Year	Yield of main panicle	Yield of average panicle	Yield of whole plant
	grm.	grm.	grm.
1922	3·7	2·9	34·5
1923	3·6	2·7	26·5
1924	4·5	3·4	36·0
General average	3·9	3·0	32·3

The character of the spikelets themselves is shown by the following determinations of their average length and breadth, while the size is shown by the number of spikelets per gram.

Year	Average length of spikelet	Average breadth of spikelet	Number of spikelets per gram
	mm.	mm.	
1922	8·30	2·40	58
1923	8·60	2·30	58
1924	8·50	2·30	54
General average	8·46	2·33	57

Summary.

It will be seen that, while all the types just described contain the general characters of the *Kolamba* rice, there is a very wide range of variation both in the botanical and in the economic characters. These may now be summarized, basing the results on the general average of each type for the years studied.

I. Plant characters.

Strain No.	Period for ripening grain	No. of fertile* tillers	Proportion of fertile tillers	Height of plant
	days		per cent.	cm.
79	110-115	6·0	91	125
164	135-140	9·2	87	141
153	135-140	9·9	95	139
32	145-150	11·1	94	141
35	145-150	9·5	95	142
42	145-150	10·4	96	137
121	150-155	9·1	85	167
104	165	12·3	87	132

*These averages will have to be slightly reduced to make an allowance for wide spacing in 1921 except in the case of Strains 153, 164, 121 and 104.

II. Panicle characters based on the main panicle.

Strain No.	Length of panicle	Number of branches	Number of spikelets	Percentage of sterility	Density of panicle
	cm.				
79	26·8	9·8	259	19	9·6
164	27·3	13·1	349	17	12·8
153	21·3	12·5	381	30	17·8
32	24·1	12·9	455	27	18·9
35	24·6	15·8	558	24	22·9
42	24·5	12·1	399	18	16·2
121	30·1	14·9	387	24	12·7
104	24·5	13·8	240	12	9·8

III. Spikelet (Grain) characters.

Strain No.	Length of spikelets	Breadth of spikelets	Number of grains per gram
	mm.	mm.	
79	9·3	2·4	51
164	9·3	2·3	56
153	8·2	2·3	70
32	7·8	2·2	78
35	7·6	2·2	79
42	8·1	2·3	68
121	8·8	2·6	51
104	8·4	2·3	58

IV. Yield of grain per panicle and per plant.

Strain No.	Yield of main panicle	Yield of average panicle	Yield per plant	REMARKS.
	grm.	grm.	grm.	
79	4·3	3·6	17·5	
164	5·1	3·6	27·0	
153	3·9	2·8	26·9	
32	4·4	3·3	32·6	These figures are high owing to uneven spacing in 1921 and consequent edge effect.
35	5·4	3·9	35·3	
42	4·8	3·3	33·0	
121	5·8	4·5	35·9	Figures available for one year only.
104	3·6	2·8	30·5	

In conclusion, we are much indebted to Dr. H. H. Mann, the Director of Agriculture, Bombay Presidency, for making valuable suggestions in presenting the facts and figures embodied in this paper.

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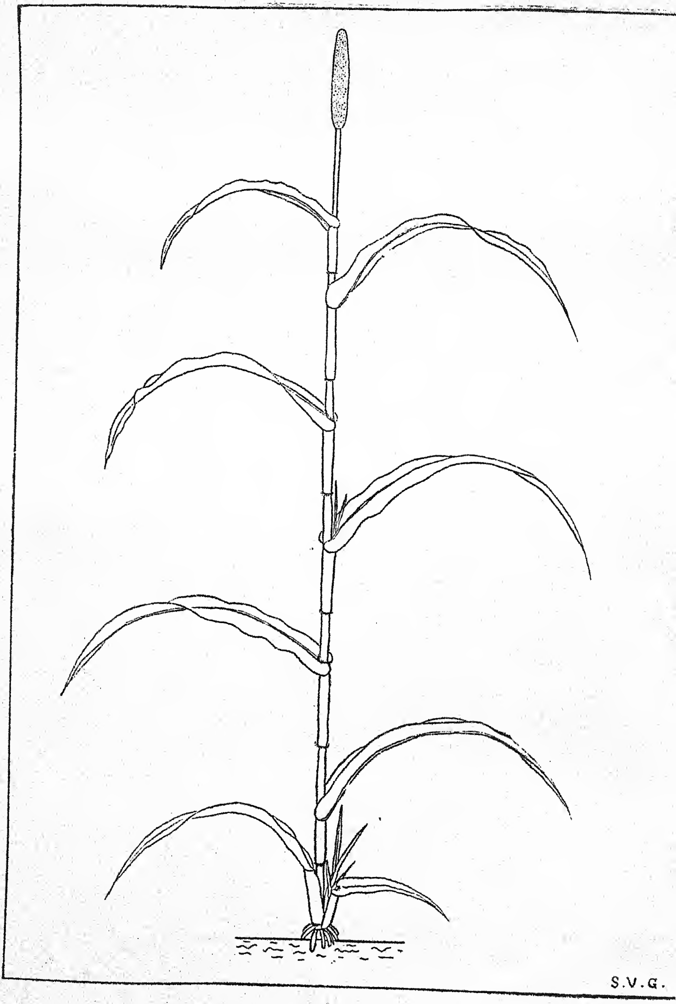

The *Bajri* plant.

PENNISETUM TYPHOIDEUM.

STUDIES ON THE *BAJRI* CROP.

I. The Morphology of *Pennisetum typhoideum*.

BY

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(Received for publication on 21st December 1926.)

Introduction.

Among the grain crops of India the fourth place is occupied by *bajri* (*Pennisetum typhoideum*), otherwise known as cat-tail millet, bulrush millet, or pearl millet. In the Bombay Presidency where the present studies have been made, it is still relatively more important, and annually occupies between four and five million acres, standing only second to *jowar* (*Andropogon Sorghum*) in the area occupied. The actual area in the several divisions of Bombay in 1924-25, the last year for which we have records, was as follows :—

	Acres
Gujarat	368,120
Deccan	2,404,659
Karnatak	303,510
Konkan	*Nil.*
Sind	1,028,729

The total amounts to 13 per cent. of the net cropped area of the Western Presidency, spread all over the province with the exception of the heavy rainfall tracts near the West coast, where it entirely disappears.

*Bajri** is the staple crop of a large tract and is the food of large classes of the people, but is grown only where it gives better results than *jowar*. It is a light soil millet while *jowar* is chiefly found on heavier soils, though on much of the land the crops are alternative, according as the weather conditions are more favourable for one or the other. It is entirely a rains crop and the area fluctuates considerably

* The general note on the crops which follows is largely taken from P. C. Patil, The Crops of the Bombay Presidency ; their Geography and Statistics. *Bombay Dept. of Agriculture*, Bulletin No. 109 (1922).

from year to year. When the monsoon opens with liberal rainfall, *jowar* occupies a larger area, while when the early rains are deficient the land put under *bajri* tends to increase. In the Deccan, the tract where *bajri* growing is most intense lies in the Western part of the so called "Desh." The crop does well on somewhat less rainfall than is required by *jowar* grown as a rains crop. In Sind, it is the dominant cereal crop of Lower Sind, next to rice, and is very largely grown here, because *jowar* is so damaged by borer (*Chilo simplex*) as to be almost a failure as a crop.

It is in very many areas grown as a mixed crop, chiefly with *Cajanus indicus* or pigeon pea. If heavy rain falls when the crop is in flower, it suffers much, and hence in the Bombay Presidency proper, it is generally sown later than other rains cereals to avoid heavy showers during this stage of its growth.

As it is generally sown on poorer land, the average yield is low, being about 400 pounds of grain and 1,000 pounds of straw per acre for the Bombay Presidency proper. In Sind the yield is very much higher.

Bajri, as a nutritious food, stands very high and compares very favourably with *jowar*. The straw, however, makes poor fodder, much poorer than *jowar* straw.

The main interest which *bajri* has, however, as an agricultural crop, is that it is highly resistent to drought, and can be grown on light and fairly shallow lands in the very precarious rainfall tracts in the Deccan and similar regions. The crop on this type of land is not a big one, but it is bigger than would be given by any other cereal, and the study, of which the present paper is the first fruit, was definitely undertaken in order to isolate strains specially highly resistent to drought. This has led to a careful morphological study of the plant itself as it occurs in Western India, and the present account is based on the material thus collected.

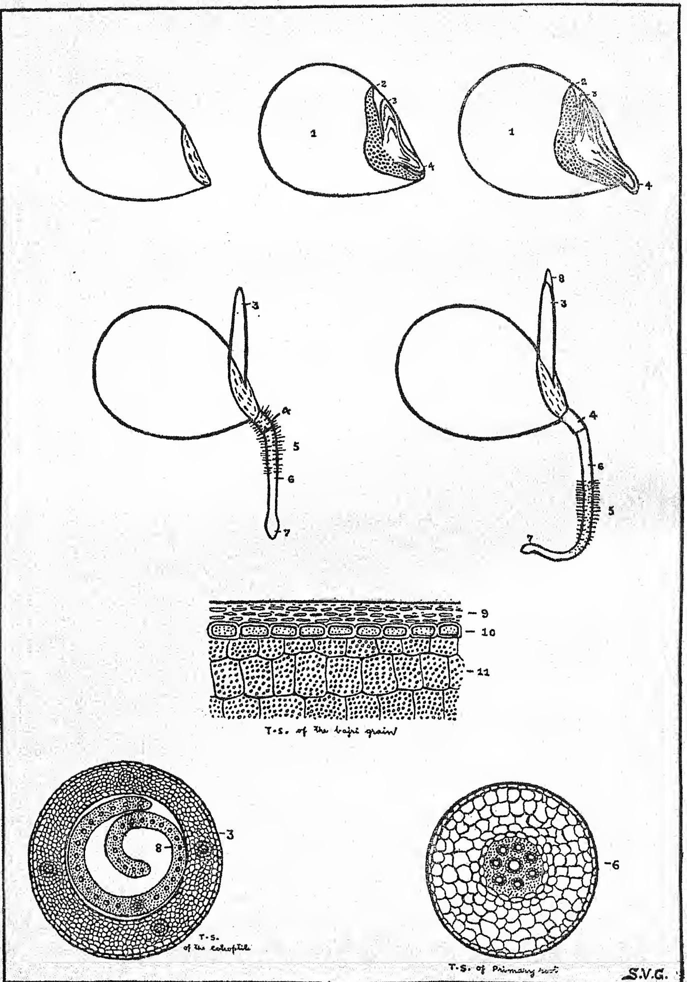
Name, History and Geographical Distribution.

The genus *Pennisetum* of the *Gramineæ*, according to Hooker, consists of thirty to forty species confined to the warmer regions of the world. About seven of these species are found in Western India, but *Pennisetum typhoideum* is the only cultivated species.

Very little is known about its history and the place of its origin. Nothing is known about its wild form. Kornicke[1] refers to the few opinions held by different authors, indicating either India or Africa as the place of origin. Sawer[2] states that it is a native of tropical Asia, Nubia and Egypt. Hooker suggests that its abundance throughout Africa would point to that continent as its source, while Ball[3] is of opinion that tropical Africa is its home.

The evidence on which some of these opinions are given depends on the wide and specialised use made of the crop in the various regions mentioned. Sawer, for

[1] F. Kornicke & E. Werner. *Handbuch der Getreudebaues*, Vol. I, P. 284 (Berlin 1885).
[2] E. R. Sawer. Bulrush or Munga millet. *Cedara Memoirs on S. Africa Agric.*, Vol. I, p. 293 (1909).
[3] C. R. Ball. Pearl millet. *U. S. A. Dept. of Agriculture Farmers' Bull.* No. 168.



The seed of *Bajri* and the young seedling.

1, Endosperm. 2. Cotyledon. 3. Coleoptile. 4. Coleorhiza. 5. Root hairs. 6. Primary root. 7. Root cap. 8. First leaf. 9. Pericarp. 10. Aleurone layer. 11. Starch parenchyma.

instance, notes that among many African tribes and particularly among the Mashonas it is used as a famine crop being planted when maize or other millets (such as *Eleusine coracana*) fail. It is valued by them as being cultivable with profit on soil too poor for maize.

Whatever be its origin, its present cultivation is very widespread. Apart from South and Central Africa, Ball notes that it has been grown in Arabia and Egypt for more than three hundred years, and that it is also extensively cultivated in Southern Europe. It was probably carried to America at a very early date, and was introduced into the United States in the fifties of the last century. There it has steadily gained appreciation of its value for grain and green fodder.

In India it is grown in all Provinces except Burma and Assam. Bombay has the greatest area, four to five million acres. Next in importance are the Punjab and the United Provinces, in each of which there are between two and three million acres. The total area in India is about sixteen million acres annually.

Structure, Viability, and Germination of the Seed.

In size and shape, the seed of cultivated *bajri* is extremely variable, being usually from 3 to 10 mgm. in weight and in appearance almost oval, with one of its ends more or less tapering. It is by this end that it is attached to the spike. Its colour varies from whitish yellow to dull light blue.

The pericarp has usually a smooth and shining surface, though there are cases when all the grains in a head have the surface very rough at the broader end. It consists of a series of elongated, thick-walled cells, five or six in number, arranged one over the other. The colour of the grain is the colour of pericarp; the contents do not vary appreciably in tint. (Plate II).

The endosperm, as in other cereal grains, fills the whole of the interior of the grain except the small space occupied by the embryo. It may be divided into two parts, the aleurone layer and the starch parenchyma. The aleurone layer surrounds the rest of the endosperm and is one cell thick, the cells being twice as long as they are broad. The starch parenchyma consists of thin walled polyhedral cells with their long axes arranged usually at right angles to the surrounding pericarp. Adjoining the aleurone layer, they are comparatively small, becoming two or three times as large in the centre of the endosperm.

The embryo consists of a short central axis terminated above by the plumule and below by the radicle, and bearing from its middle portion the large cotyledon. The plumule remains completely enclosed in the firm cylindrical coleoptile.

Viability. Very few data could be obtained as to the length of time during which the seed remains viable under the conditions of the Bombay Deccan. We were able to make tests in 1925 of samples from the crop of every year since 1919. These had been stored with naphthalene balls to keep off insects. The seed of 1919 had been kept in a bottle; all the rest had been preserved in paper packets.

The results of germination tests with this stored seed in 1925 were as follows :—

	Per cent. germination.
1919	51
1920	37
1921	73
1922	88
1923	93
1924	97

The higher figure for 1919 over 1920 may be the result of keeping the former in a bottle.

Germination of bajri seed. When *bajri* seed is placed under suitable conditions for germination, it first absorbs 50 per cent. of water and swells. In twenty-four hours the coleorhiza appears from the pericarp and twelve hours later the primary root breaks out. Almost at the same time, the plumule breaks through the pericarp. The coleoptile remains intact, however, until it reaches the surface of the soil. (Plate II.)

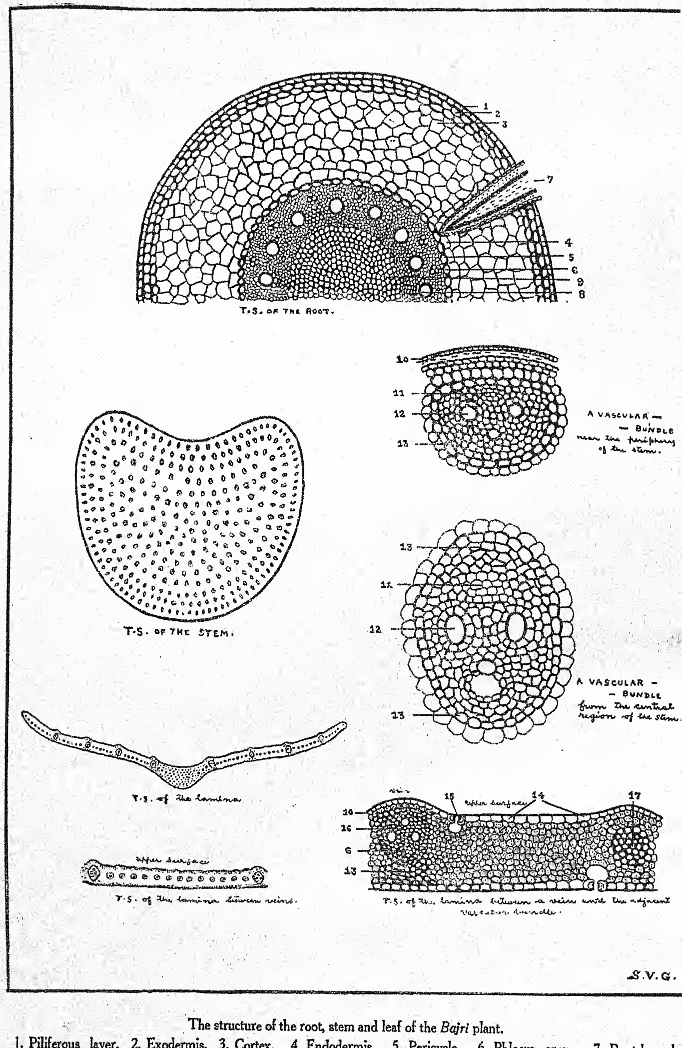
The depth to which *bajri* seed may be planted with success has an important bearing on the question of the improvement of the crop. Planting at different depths was tried in the case of the Deccan variety in the cold as well as the rainy season. The cold weather results show that in all cases where the seeds were planted more than ten centimetres deep, no leaves were able to reach the surface, and that the maximum elongation of the epicotyl was only six centimetres.

In the wet season seedlings from such depths as thirteen centimetres have come above the ground and the maximum elongation of the epicotyl in their case was ten centimetres.

The Root System of Bajri.

The embryonic plant gives rise to only one primary root, which on bursting through the coleorhiza continues downwards giving rise to lateral branches throughout its length. The lateral branches are extremely delicate, being not more than one-fifth of a millimetre in diameter. The work of the primary root is soon supplemented by secondary roots, springing from the first and still higher nodes of the plant. These do not begin to appear until two or three leaves have appeared above the surface. The first to rise is a pair of roots from the first node of the plant, each of them being one right angle away from the first axillary bud. These do not, however, appear simultaneously on both sides.

On the second node, another pair develops in like manner, and from each succeeding node two further roots appear, arranged similarly with regard to the nodal bud. At the base of the stem, near the ground, where the internodes are longer, four or six roots are produced at each node. The upper series of these usually form very strong props, which assist in keeping the plant erect. Each tiller develops its



The structure of the root, stem and leaf of the *Bajri* plant.

1. Piliferous layer. 2. Exodermis. 3. Cortex. 4. Endodermis. 5. Pericycle. 6. Phloem group. 7. Root branch. 8. Xylem group. 9. Pith. 10. Epidermis. 11. Phloem. 12. Trachea. 13. Sclerenchyma. 14. Hygroscopic cells. 15. Stoma. 16. Xylem. 17. Vascular bundle.

own independent system of secondary roots, which follow the same general arrangement in pairs as that of the primary stem.

Types of root system. The root system of a good many plants has been examined by * Weaver's method, which though laborious seems satisfactory. The following notes were made as a result of the examinations made by this method.

(1) In tillered plants, the root system spreads very widely in all directions, the extent being largely determined by the number of tillers.

(2) The horizontally spreading roots are confined to the uppermost ten or twelve centimetres of soil. They are, however, much thinner than those which go downward.

(3) Each secondary root starting from the base of the plant, gives off very thin lateral branches at angles varying from seventy to ninety degrees.

(4) Types of *bajri* with a spreading habit have a much greater amount of horizontal roots, and these are mostly confined to the surface layers of the soil.

(5) When the vertical roots penetrate crevices in *murum* (the soft rock resulting from the degradation of Deccan trap) they become very much thickened, apparently as a means of widening the crevices.

(6) The excavated plants which were allowed to remain connected with the soil by a very few roots, continued to live normally for the rest of their life,—over four weeks,—and flowered and fruited quite normally. This gives an idea as to how the plant can flourish on a very much diminished root system.

(7) When sub-irrigation was used in pots, the roots altered their character and were largely attracted to the moist layer, and even to the lowermost layer of gravel in pots 26 inches deep.

Anatomy of the roots. A transverse section through a well developed root shows the following tissues (Plate III) :—

(1) The outer piliferous layer of thin-walled elongated cells, from many of which root-hairs are developed.

(2) The exodermis consisting of two or three layers of thick-walled cells beneath the piliferous layer.

(3) The broad cortex made up of five or six layers of thin parenchymatous cells.

(4) The endodermis, which is a single layer of cells with thick inner walls.

(5) The pericycle, consisting of one layer of cells, with cell walls thickened on all sides.

(6) The xylem and the phlœm groups arranged alternately in a ring, and lined from within by a band of sclerenchymatous fibres.

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*J. E. Weaver. Ecological Relations of Roots. *Carnegie Institute, Wash. Pub.* 286. (1919).

(7) The central portion of the stele consisting of moderately thick-walled parenchymatous cells.

The Stem of the Bajri Plant.

The stem which originates from the embryonic shoot grows on continuously into the shoot proper and consists of several segments or internodes joined together by structures known as nodes. The whole length of the lower and much of the upper internodes is invested by leaf sheaths. From each node there is produced one leaf and one axillary bud. The latter may either remain dormant or grow into a tiller or axillary shoot according to its position under or above ground. At the uppermost node, however, the bud is absent and from that node the inflorescence appears.

The Internode. The lengths of several internodes increase from the base to the apex of the stem except the lowermost four or five which are very condensed. About the time of flowering, the topmost internodes, however, show an extraordinary rate of increase in their length. Each individual internode is thickest in the middle and tapers more or less evenly towards both ends. It does not possess any cavity within. Its thickness also varies considerably, 4-7 mm. being the usual range of diameter at the middle. In some varieties, hairs are also found on the upper part of the internodes which are not covered over by leaf sheaths. Frequently, internodes of a reddish colour are also met with, especially at the base of plant.

The node. The nodes of an individual plant are all hairy, the quantity of hairs at each node increasing from the base to the apex of the stem. The extent of hairiness also varies in different strains, some being more hairy and others less so. Very frequently, plants with reddish or reddish brown nodes are met with.

The length and thickness attained by an individual plant is influenced by a number of independent factors and varies very much according to the variety and other conditions. In crops of the local variety grown by the author at Poona, the height has in extreme cases reached 203 centimetres (81 inches), but most frequently was between 100 and 150 centimetres, (40 to 60 inches). (Plate VI. Fig. 1-A.)

Anatomy of the stem. A transverse section through the stem presents the following structures. (Plate III.)

(1) The epidermis consisting of a single layer of cells with walls very much thickened from outside.

(2) The cortex consisting of one or two layers having more or less thickened cell walls.

(3) The ground tissue made up of thin-walled parenchyma extending from the cortex to the centre of the stem.

(4) The vascular bundles: in the peripheral region of the stem there are usually broader and more closely distributed than those in the central part. They contain air spaces on the inner side of the xylem portion and are surrounded by sheaths of sclerenchyma.

Tillering in the Bajri Plant.

Although tillering is of very frequent occurrence in the *bajri* plant, and though it may arise from any of the underground axillary buds either of the main stem or of its branches, yet it is only found to a small extent among the plants of a field crop of *bajri*. As studied in the case of the Deccan variety at Poona in 1921, the following shows the extent of its occurrence among plants in rows in the middle of an ordinary field of this crop :—

	per cent.
Plants without tillers	75·4
Plants with one tiller	10·6
Plants with two tillers	9·3
Plants with three tillers	4·0
Plants with four tillers	0·7

The absence of tillers does not, therefore, arise from any lack of capacity to produce tillers, and these latter develop profusely when plants either occur near a water channel, or are widely spaced, or are highly manured. When the main shoot is arrested in growth owing to disease or damage, tillers develop profusely and if the main shoot lies flat owing to trampling or to heavy rain, tillers will spring up in large numbers. Plants growing in the cold weather and consequently stunted, often give many tillers; and late varieties have often a larger number of tillers than others.

Axillary Branches or Shoots in Bajri.

The presence of frequent axillary branches, arising from the axils of the main stem, is rather characteristic of the *bajri* plant. They are not, however, anything like so vigorous as the tillers referred to above, and only develop usually two or three internodes. They are found with very great frequency in lodged plants and in those from which the upper portions of the main stem are cut off.

The relationship between the number of tillers and such axillary branches was determined in the central portion of a *bajri* field of the Deccan variety in 1921. 301 successive plants were examined with the following results :—

Number of tillers.

No. of axillary shoots	No tiller		One tiller		Two tillers		Three tillers		Four tillers	
	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.
0	179	78·8	20	62·5	17	10·7	3	25·0	2	100·0
1	34	15·0	7	21·9	5	17·9	4	33·3	0	0·0
2	9	4·0	4	12·5	5	17·9	3	25·0	0	0·0
3	3	1·3	0	0·0	1	3·5	1	8·3	0	0·0
4	2	0·9	1	3·1	0	0·0	1	8·3	0	0·0

It will thus be seen that there seems to be a greater portion of axillary shoots among tillered plants than among those without tillers. This may mean that the environment which favours tillering also favours branching, or it may mean that plants which tend to produce tillers also tend to produce the other type of branches.

The Foliage Leaves.

The foliage leaves of *bajri* are arranged on the culms alternately, in two opposite vertical rows, each leaf having a divergence of 180° from the next above and below it.

The sheath, which is somewhat thicker than the lamina, encircles the culm completely. The inner portion of the sheath is rather white and somewhat transparent. The outer surface of the sheath is usually glabrous ; but there are some plants often found in this crop in which the outer surfaces of the sheaths are clothed with short hairs. This hairiness is, as a rule, associated with that of the lamina. Occasionally sheaths, especially basal ones, with a reddish outer surface are also met with.

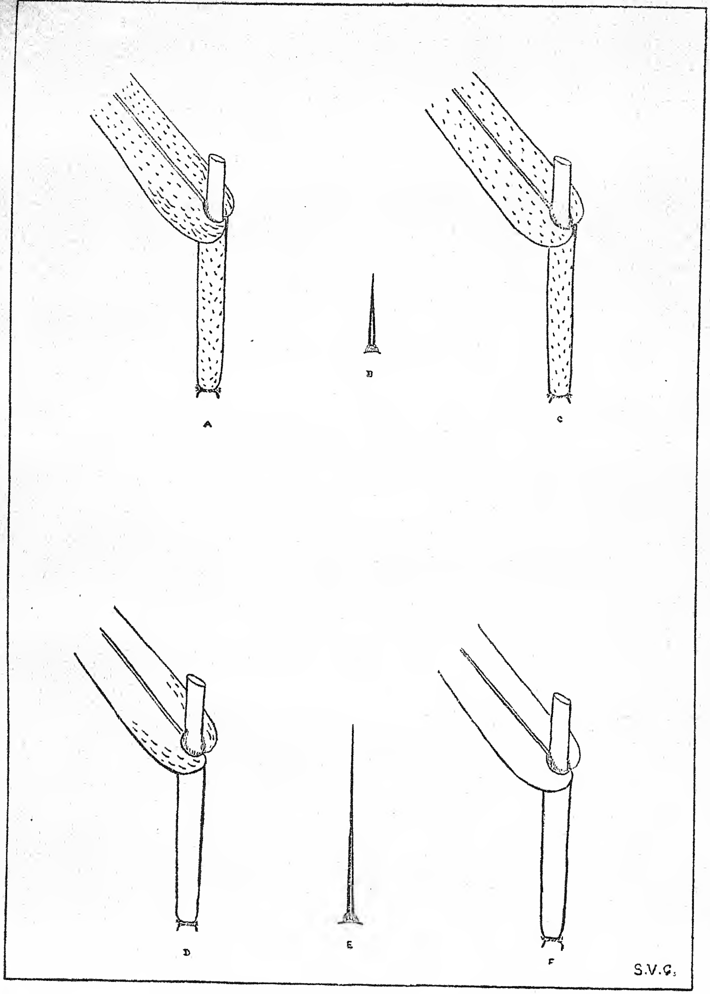
The lamina or the leaf blade is linear and parallel veined. The upper surface of the blade possesses a series of longitudinal and slightly raised ribs which are absent on the lower and hence the lower surface is usually smoother than the upper one. In the majority of plants the basal portion of the lamina possesses hairs along the upper margins, while plants without hairs also exist. These hairs, being three to four times longer than the sheath and lamina hairs, can be easily distinguished from the latter. When the lamina is hairy, hairs similar to the sheath ones are to be found on both the surfaces throughout. (Plate IV.)

The ligule closely surrounds the stem just above the leaf sheath, and is a small white structure four to five mm. in length with hairs starting from its edge.

The length of different leaf blades varies according to their position on the main stem. When the aerial part of the stem possesses four or five leaves only, the third leaf from the top is usually the longest and that next above it will probably be the broadest ; but in cases of stems having six or seven leaves, the fourth leaf from the top will have the maximum length and the one immediately above it will have the greatest width. Thus, the position of the leaf having the maximum length or breadth on the main stem will descend with the increase in the total number of leaves.

Stomata are found on both surfaces of the leaf approximately to the same extent. The number of stomata per square millimetre on the lower surface varies usually from fifty to eighty, the vigorously growing plants possessing a smaller number.

Anatomy of the leaf. The epidermis of the leaf blade consists of rectangular cells arranged in parallel rows along the long axis. (Plate III). Parallel to the midrib of the leaf blade and spaced at regular intervals there is a series of veins each having a single vascular bundle. These vary in size, every tenth to fifteenth one being much larger than the others. The larger veins are found to be slightly raised on the upper surface while they are flush with the lower.



The characters of the sheath and lamina hairs of the *Bajri* plant.

A. Long hairs at the base of the lamina and short hairs all over the sheath and lamina. B. A short hair. C. Short hairs all over the sheath and lamina. D. Long hairs at the base of the lamina. E. A long hair. F. Absence of hairs.

The epidermal cells over the veins are usually elongated and thick-walled. Unicellular hairs which are present on both the surfaces of the lamina are found on the side of these veins especially the larger ones. At the bases of the veins on both sides there is usually a single line of stomata.

Between two veins of the upper epidermis there occur longitudinal groups of motor or hygroscopic cells which contain water under normal conditions. When transpiration is excessive these cells lose their water content and cause the upper surface to shrink and curve inwards, tending to check any further loss through the stomata.

Vascular bundles found usually below the large veins are similar to those of the stem. They possess sheaths of sclerenchyma often extending up to the epidermis. The xylem and the phlœm of these bundles are situated towards the upper and the lower surfaces respectively. The smaller bundles possess sheaths of cells containing a large amount of chlorophyll.

The Bajri Inflorescence.

The inflorescence of *bajri* is a terminal compound spike with a variable number of rachillæ spirally arranged round the central axis. The rachillæ, which vary considerably in their length, bear at their apex a whorl of bristles enclosing usually two spikelets, each of which consists of a male and a hermaphrodite flower. The rachillæ, spikelets, flowers, etc., will be discussed under separate headings.

The node at which the inflorescence is borne on the main stem. Within five or six weeks from sowing, the *bajri* plant puts forth its inflorescence. This is, however, marked by the rapid increase in the height of the plant owing to the lengthening of the peduncle and the internodes below it. Earliness or lateness is roughly determined by the number of internodes that the plant possesses, since the period of growth will also increase along with the number of internodes. It was thought necessary to possess some data as to the variation in the number of internodes that the main stem has under crop conditions. This could not be done completely owing to the great difficulty of counting the internodes below the ground level and hence the counting had to be confined to the aerial portions only.

For this purpose the node at which the inflorescence appeared, counting from the ground level, was recorded in 1921 in the case of 297 plants of the Deccan variety of this crop occupying the centre of a normally grown field. The following results were obtained.

	Per cent.
Plants with three nodes below inflorescence	1·0
Plants with four nodes below inflorescence	25·3
Plants with five nodes below inflorescence	38·0
Plants with six nodes below inflorescence	31·0
Plants with seven nodes below inflorescence	4·4
Plants with eight nodes below inflorescence	0·3

Five internodes was the most frequent number possessed by 38 per cent. of the crop plants. Three and eight internodes were the extreme cases. (Plate VI, Fig. 1. B).

The rachis. The rachis or the axis of the inflorescence is a straight solid cylindrical structure, as long as the length of the earhead. It tapers more or less gradually towards its apex. It possesses a thick coating of soft short hairs all over. It is usually unbranched and in rare cases it may divide itself into two or three branches. An extremely rare instance was noticed in which it possessed in all seven branches.

The thickness of the rachis varies considerably. In some varieties, for instance in the *Gajwel* variety, the circumference often measures as much as twenty-five millimetres, while in the Deccan variety it is much less. The measurements of fifty rachides chosen at random from a normally grown crop of the Deccan variety are given in the following Table :—

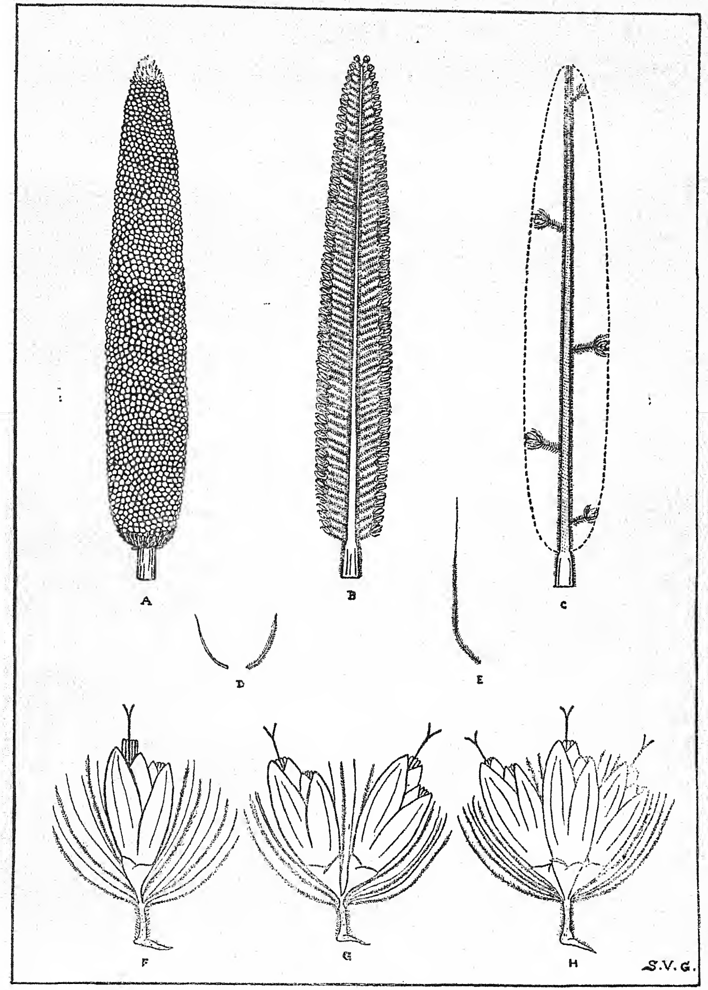
Circumference of the rachis at the middle	mm. 5	mm. 6	mm. 7	mm. 8	mm. 9	mm. 10	mm. 11
Number of ear heads in each	1	1	11	15	15	6	1
Percentage	2	2	22	30	30	12	2

Eight or nine millimetres was the most frequent circumference of the rachis with five and eleven millimetres as extreme cases. The plants did not include any types with thick rachis. (Plate VI, Fig. 2-A.)

There seems to be a negative correlation between the thickness of the rachis and the length of the rachilla. The rachillæ have very short length in the case of heads having very thick rachis, but the reverse is true only to a limited extent, for thin raches are not necessarily associated with long rachillæ.

The rachillæ. The rachillæ or the secondary axes of the inflorescence are a series of small structures arranged spirally round the central axis, each carrying a group of spikelets enclosed in a whorl of bristles at their apex. They are inclined to the rachis at varying angles, the ones in the middle being usually of 80°, while those towards the base and the apex gradually decrease until they become as small as 30°. The surface of the rachillæ has a thin covering of elongated hairs unlike that of the main axis. (Plate V A—E.).

In thickness the rachillæ are scarcely a millimetre, but their length varies considerably from 1 to 7 millimetres in different types and also in different regions of the same spike. In types with a very thick rachis, the rachillæ are extremely short, so also in some other varieties of this crop, for instance the African bulrush millet. The rachillæ in the second or the third fifths of a spike are usually the longest, while those below and above it gradually shorten until their length reaches its minimum in the uppermost part of the spike.



The earhead of the *Bajri* plant.

A. An earhead. B. An earhead showing the arrangement of rachillæ. C. A rachis with a few rachillæ. D. Ordinary bristles with and without hairs. E. An elongated bristle with hairs. F. A rachilla with one spikelet. G. A rachilla with two spikelets. H. A rachilla with three spikelets.

The length of the rachillæ and their inclination to the rachis are together partly responsible for the thickness of a particular region of the spike. In cases with very short rachillæ, the deficiency is usually made up by the greater thickness of the central axis. The varying length of spikelets also contributes to some extent to the thickness of the spike.

The number of rachillæ per earhead. In order to study the variation in the number of rachillæ per earhead, fifty main earheads were selected at random from a normally grown crop of the Deccan variety of *bajri*. The results are given in the following Table :—

No. of rachillæ per ear head	500	600	700	800	900	1000	1100	1200	1300	1400
No. of earheads .	2	4	6	10	7	7	6	2	5	1
Percentage . .	4	8	12	20	14	14	12	4	10	2

Eight hundred rachillæ per earhead is the most common type met with in the Deccan variety, though the number may go to five hundred and fourteen hundred in extreme cases. (Plate VI, Fig. 2-B.)

The average number of rachillæ in different parts of the earhead. In the case of the fifty earheads already referred to, the distribution of the rachillæ in five equal divisions of the head was studied and the average number found in each part is shown in the following Table :—

Average No. of rachillæ in different fifths of earheads	PARTS OF EARHEAD				
	BASE..........TO..........APEX.				
	135	202	226	211	152
Average total No. of rachillæ 924 (=average of 50 heads). Percentage.	14·4	21·9	24·4	22·8	16·5

The number was maximum in the middle one-fifth, but it decreased gradually in both directions. (Plate VII, Fig. 1-A.)

The density of rachillæ. The number of rachillæ on the unit surface of the rachis at its middle was studied in the case of the fifty earheads already mentioned. The middle portion, which is less liable to vary in thickness, was thought to be more suitable for comparison. The results obtained are given in the following Table :—

No. of rachillæ per Sq. cm.	50	60	70	80	90	100	110	120	130	140	150	160	170	180
No. of earheads (Total 50).	2	2	4	8	10	8	4	3	3	2	3	0	0	1
Percentage . .	4	4	8	16	20	16	8	6	6	4	6	0	0	2

The figures show that there is a great variation in the density of the rachillæ in the middle portion of the earhead. Fifty and one hundred and eighty rachillæ per square centimetre were the extreme cases found. Ninety rachillæ per square centimetre was the most frequent number in earheads of the Deccan variety. (Plate VII, Fig. 1-B.).

The Spikelets. It has been already stated that at the end of each rachilla there is a whorl of bristles enclosing several spikelets—usually two. The whorl consists of 35 to 40 bristles when it encloses only one spikelet, but the number of bristles goes on decreasing along with the increase in the number of spikelets within the whorl. The bristles are almost as long as the spikelets, slightly curved in shape and possess a scabrid surface. The outer ones are not hairy and are somewhat shorter than the inner ones, but the latter, though hairy, sometimes drop their hairs especially from the upper portions of the bristles. In thickness the inner ones slightly exceed the outer. In awned varieties some of the inner bristles elongate three to five times their usual length and form what are known as awns. The bristles or the awns in some cases have a pinkish colour varying widely in intensity.

Enclosed within the whorl of bristles there is a group of spikelets usually two, but the number may vary from spike to spike and also in different parts of the same spike. There are usually two flowers in the spikelet, the lower one being male and the upper hermaphrodite. The length of the spikelet varies from 3 to 6 millimetres in different types.

The total number of spikelets in the earhead varies considerably in different types according to the number of rachillæ and also the number of spikelets on each rachilla. In order to have some idea as to the variation of this number, the fifty earheads already referred to were examined and the results obtained are shown in the following Table :—

No. of spikelets	875	1,125	1,375	1,625	1,875	2,125	2,375	2,625	2,875	3,125
No. of earheads	2	3	8	13	9	7	5	1	1	1
Percentage	4	6	16	26	18	14	10	2	2	2

The most frequent number of spikelets per earhead is 1,625, with 875 and 3,125 as extreme cases. (Plate VII, Fig. 2-A.)

The average number of spikelets in different parts of the earheads. The distribution of the spikelets in different parts of the earheads was also studied side by side in the above fifty earheads. The earhead was divided into five equal lengths and the

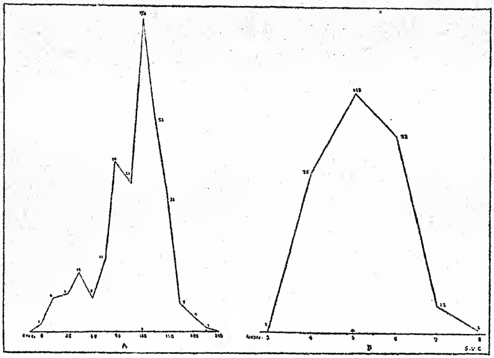


FIG. 1.

A. Frequency curve showing the height of plants.

B. Frequency curve showing the node at which the earhead is borne.

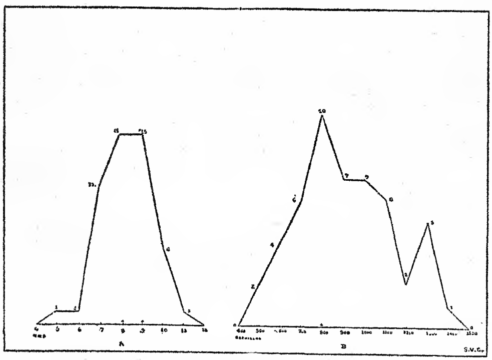


FIG. 2.

A. Frequency curve showing the circumference of the rachis at the middle.

B. Frequency curve representing the number of rachillæ in different earheads.

PLATE VII.

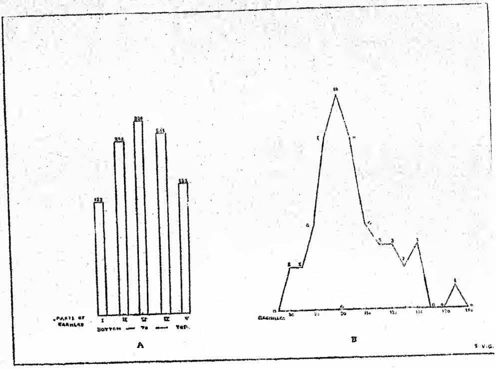


FIG. 1.

A. Average number of rachillæ in different parts of earhead.

B. Frequency curve showing the number of rachillæ per square centimeter.

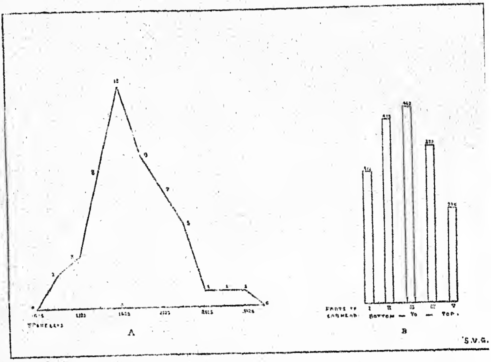


FIG. 2.

A. Frequency curve showing the number of spikelets in earheads.

B. Average number of spikelets in different parts of earhead.

number of spikelets noted in each division. The average number found in each part is shown in the following Table :—

Parts of earheads	BASE..............TO......APEX				
	1/5	1/5	1/5	1/5	1/5
Number of spikelets in each. Total 1810.	312	438	462	372	226
Percentage	17·3	24·2	25·5	20·5	12·5

More than twenty five per cent. of the total number of spikelets were found in the middle fifth of the earhead and the number gradually decreased towards both ends of the earhead. The extent of the decrease in the upper part was much more than that in the lower part of the earhead. (Pl te, VII, Fig 2-B).

Different number of spikelets found on the rachillæ. In order to study the variation in the number of spikelets found on the rachillæ, the rachillæ of the above fifty earheads were examined and the number of spikelets in each case was noted. The groups of rachillæ bearing different number of spikelets are shown in the following Table and also represented in Plate IX, Fig. 1-A.).

No. of spikelets	1	2	3	4	5	6	7	8	9	10
No. of rachillæ. Total 46,247.	7,646	33,651	4,498	364	61	20	6	0	0	1
Percentage	16·5	72·8	9·7	·8	·15	·05	0	0	0	0

The number of spikelets varied widely from 1 to 10 per rachilla. More than seventy-two per cent of the rachillæ bore two spikelets each. Amongst the rest those with one and three were present to an extent of twenty-six per cent. All the rest did not form even one per cent. of the total number. (Plate IX, Fig. 1-A.).

Variation in the number of spikelets per rachilla in different parts of the earhead. The average number of rachillæ found in each of five equal parts of the earhead. has already been given, while the number of spikelets borne by those rachillæ has been also mentioned. From these two figures, the number of spik lets per 100 rachillæ in different parts of the earhead has been obtained and shown in the following Table, as also in Plate IX, Fig. 1-B)

Parts of earhead	BASE................TO......APEX.				
	1/5	1/5	1/5	1/5	1/5
Number of spikelets per 100 rachillæ	235	216	204	176	148

The average number of spikelets per rachilla in five equal parts of earhead decreases from below upwards. In the lowermost one-fifth, it is 2·35, in the middle slightly above 2, and in the top one-fifth it is approximately 1·5 per rachilla. (Plate IX, Fig. 1-B.).

The bajri flower. The spikelet which is shortly pedicelled is usually ovate or oblong in form. It consists of two flowers lying closely together, of which the hermaphrodite one is slightly longer than the other which is staminate. (Plate VIII.)

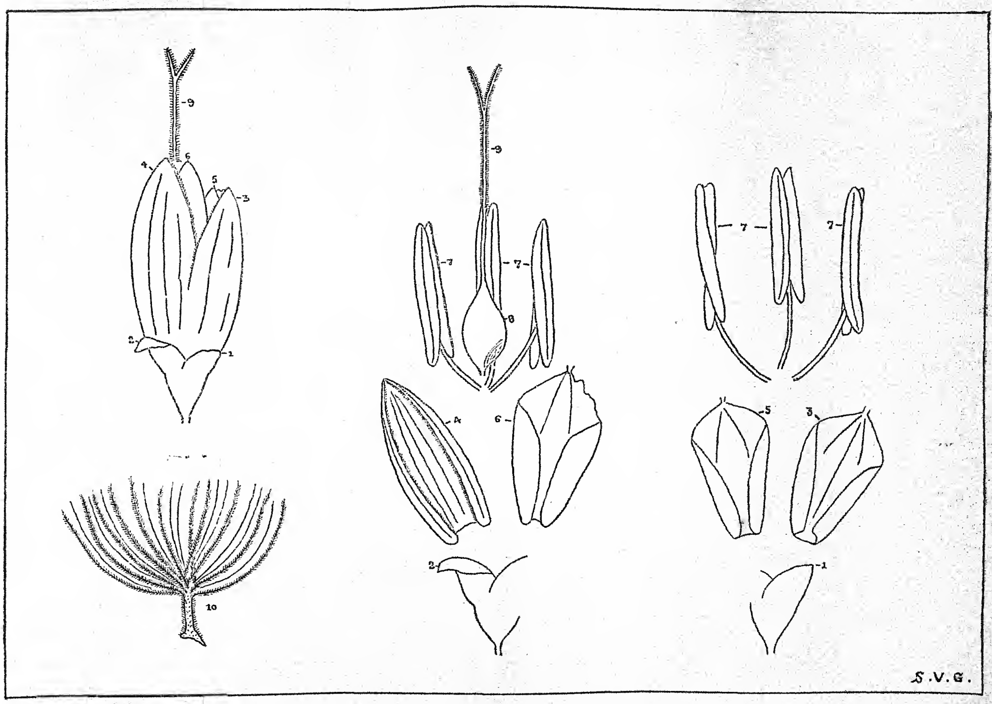
The empty glumes (I & II) are quite rudimentary often reduced to small membranous bands. The two inner glumes (III & IV) differ slightly from one another in form. Glume III which contains the staminate flower, is somewhat smaller than glume IV and slightly broader at the apex and possesses only 3 nerves, while glume IV which contains the hermaphrodite flower is ovate, 3·5 mm. long, glabrous, 5-7 nerved, with incurved ciliate margins and acute apex. The paleae in both cases are two nerved, broad, delicate, thick and translucent structures encircling the stamens. Lodicules are however absent. The stamens are three with filiform filaments and versatile linear anthers. The ovary is monocarpellate, one-celled, containing a single ovule. The style which divides itself into two branches in its upper part possesses stigmatic hairs over its surface, each of which is capable of admitting pollen tubes.

Variation in the nature of flowers. A slight variation from the usual nature of the flowers in spikelets has been found in a very few instances. In all cases of involucels containing one spikelet, the flowers of the normal type, *i.e.*, one hermaphrodite and one staminate, were found. In cases having two spikelets each, the staminate flower was absent in one or both spikelets. When the involucels contained three spikelets, one of them possessed both flowers staminate. Lastly, only in one case of an involucel containing four spikelets, the staminate flower was absent in one of them. In no case, the spikelet consisted of more than two flowers.

Pollination. The main inflorescence of *bajri* emerges within five to ten weeks from the date of sowing, but this period may vary according to variety, climate and other unknown factors. The appearance of the spike is accompanied by the rapid elongation of the peduncle and also the internodes below it.

Two to three days after its emergence, styles begin to protrude first at the top, then gradually downwards, requiring usually twenty-four hours to reach the base of the spike. The styles, to attain their full length of 5 to 7 mm., require thirty-six to forty-eight hours and after remaining fresh for a day or two later, they begin to dry up.

Just after the styles have started drying up or a little later, the anthers push themselves out of their glumes, first in the region slightly above the middle of the spike and continue to appear both upwards and downwards, taking usually forty-eight hours to reach the basal portion. Late in the season, the styles, as also the anthers, take a longer time to finish their protrusion and sometimes the anthers start appearing from the top instead of slightly below it.



The structure of the *Bajri* flower.

1. Glume I. 2. Glume II. 3. Glume III. 4. Glume IV. 5. Palea I. 6. Palea II. 7. Anther. 8. Ovary. 9. Style. 10. A whorl of bristles.

In any spikelet, the anthers of the hermaphrodite flower appear two to three days earlier than those of the staminate. The same thing happens when there are two or more spikelets in an involucel. This is how a new series of anthers is often seen protruding from regions already covered with anthers.

The opening of the anthers takes place from the tip downwards. They have been found to dehisce at any hour during day time, but evidence is lacking as to what extent this happens during the night. Early in the morning, however, a great many anthers are usually seen undehisced, which suggests that the dehiscence has either stopped or proceeded at a slower rate.

The protogynous nature of the flowers as described above suggests the vast extent of cross-pollination that is taking place in this crop. Even if there be a larger number of styles looking quite fresh when the anthers first appear, the abundance of foreign pollen already floating in the air scarcely provides an opportunity for self-pollination to take place. In the lowermost part of the spike, however, the styles, owing to their late emergence stand some chance of coming across pollen derived from the same inflorescence.

If the access of foreign pollen be prevented by putting over the spike a close-meshed cloth bag immediately after its emergence, the styles that appear within do not dry up as early as they do when exposed. This is probably due to the greater humidity within the bag and also the delayed (here, self) pollination which does not induce them to dry up earlier. The bagged earheads set well and produce grains all over to the fullest extent.

Individual cross-pollination is too difficult to practise to any extent. It has been observed that the styles and also the anthers in the lowermost part of the spike are the last to appear ; but the time taken by the anthers to spread to the lowermost part of the spike is much more than is required by the styles. Thus the interval between the appearance of the styles and the anthers is greater in the lowermost region than in any other. This difference in period may be taken advantage of in cross pollinating *bajri* flowers. The first step would be to cut off the upper four-fifths of the spike and bag the rest before any styles appear. After two or three days when the styles appear fully, pollen from a previously bagged inflorescence should be brought and dusted over the styles, taking care not to expose the latter except during the period necessary for the operation. The above should be repeated three to four times at convenient intervals before any anthers appear. If, however, the pollination is delayed, the styles may not dry early with the result that the anthers in that region may appear and vitiate the purpose.

In seven to eight days from the first appearance of the spike, the emergence of anthers comes to a close and the development of the ovary commences. By the end of the first week of its growth, the ovary grows so much as to become visible outside the glumes and its contents, which were watery in the beginning, begin to turn milky. A week later, it is found to have developed into a full-sized grain. During the following week, the grain hardens gradually while the colour also changes from white to dull bluish green.

The Bajri Earhead.

The earhead is the most important part of the plant that has to be studied in detail. The advantages or otherwise of any variation in the plant will have, in most cases, to be judged by the size of the head and by the grain yield.

From the time of the first appearance of the spike to the complete ripening of the grains, the period is usually four weeks or slightly less. In late varieties this period is slightly more, but there are no further data to show as to whether this period is proportional or not to the total life period of such late plants.

In shape, the earhead varies considerably in different varieties. The most common form of earhead is a cylinder with a slightly tapering cone in the uppermost one-third. Perfectly cylindrical heads are also found especially in varieties with very short rachillæ. At times, the lower portion of the cylinder is reduced in thickness and spindle-shaped earheads are formed.

The compactness or looseness in earheads is a combined result of three different factors. The first of these is the distribution of rachillæ on the surface of the rachis. Evidently, the greater the number per unit surface, the more will be the compactness. The length of rachilla is another factor that affects compactness. When rachillæ are short, the earhead appears compact, and as their length increases, the space surrounding each group of spikelets will naturally increase, thereby causing sparseness or looseness in earheads. The third factor is, however, the space that is occupied by each group of spikelets which increases with the size and number contained in each involucel.

The length. The length of earhead is subject to extreme variation depending on the variety, season, soil, moisture, manure, etc. In certain varieties, for instance Gajvel, long earheads with very short rachillæ are formed while in some others thick and short earheads are usually produced. The Deccan variety, however, produces a medium-sized earhead, neither long nor broad. In order to study the variation in the length of earheads in the Deccan variety, one hundred and fifty earheads were selected at random in a normally grown crop and their length measured. The results are shown in the following table :—

Length of earhead in cm.	9	10	11	12	13	14	15	16	17	18	19	20
No. of heads. Total 150 . .	3	7	19	22	30	29	14	14	5	2	3	2
Percentage . . .	2	4·7	12·7	14·7	20	19·3	9·3	9·3	3·3	1·3	2	1·3

Thirteen centimetres is the most frequent length in earheads that have been examined. Nine and twenty centimetres were the extreme cases. The above should not be taken to mean that there can be scarcely any earheads beyond the limits mentioned above. (Plate IX, Fig. 2-A.).

The circumference. The circumference which varies according to the diameter or the thickness of the head is dependent on three factors. The first of these is the

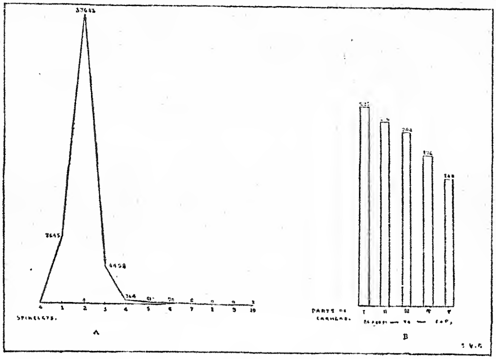


Fig. 1.

A. Frequency curve of the number of spikelets on one rachilla.

B. Average number of spikelets per hundred rachillæ in different parts of earhead.

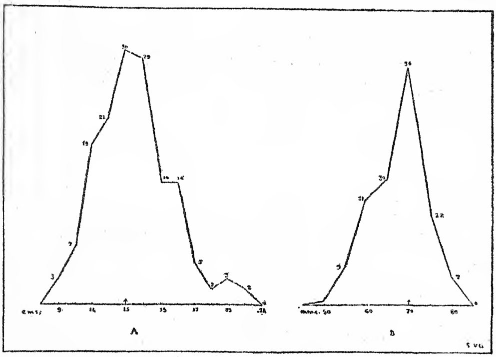


Fig. 2.

A. Frequency curve showing the length of earheads.

B. Frequency curve showing the circumference of the spike.

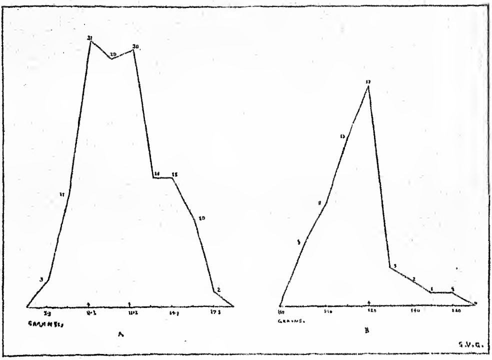


FIG. 1.

A. Frequency curve showing the grain yield of earheads in grammes.

B. Frequency curve showing the number of grains per gramme in different earheads.

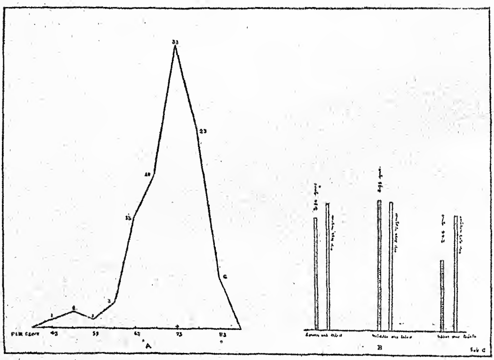


FIG. 2.

A. Frequency curve of the grain percentage in different earheads.

B. Comparison of the size and quantity of grain in different parts of earheads.

thickness of rachis; the second, the length of rachillæ and the third, the length of the spikelets. It has been mentioned in a previous chapter that in the case of inflorescences having thick rachis, the rachillæ are rather short. The variation in circumference has been studied in the case of the same one hundred and fifty earheads selected for the length measurements. The analysis of the figures is shown in the Table below and graphically in Plate IX, Fig. 2 B.

Circumference of the spike in cm	5·0	5·5	6·0	6·5	7·0	7·5	8·0
Number of heads. Total 150	1	9	25	30	56	22	7
Percentage	·7	6·0	16·7	20·0	37·3	14·7	4·7

Seven centimetres was found to be the most frequent circumference, while five and eight centimetres being extremes. Plate IX, Fig. 2 B.

The grain yield. The weight of grains obtainable will vary according to the fertility and the size of the earhead. At times, most of the grains that have formed are eaten by birds in spite of the watch kept to prevent such loss.

Infertility has been often stated to be a consequence of pollen having been washed away by rain during the flowering season; but it is often found that soon after the rains some of the styles drop off in a fresh state. It is not certain as to what extent the infertility may be attributed to the washing away of the pollen or to the dropping of the styles at about the time of fertilisation.

The variation in grain yield in the Deccan variety was, however, studied in the case of one hundred and fifty earheads already referred to in this chapter. The figures are classified under groups differing by 1·5 grams and the number of individuals falling under each group is shown in the Table below :—

Weight of grains in grams .	5·3	6·8	8·3	9·8	11·3	12·8	14·3	15·8	17·3
No. of heads. Total 150 .	3	13	31	29	30	15	15	10	2
Percentage	2·0	8·7	20·7	19·3	20·0	10·0	10·0	6·7	1·3

Though the maximum number of individuals fall under the class of 8·3 grams, the two neighbouring classes, *viz.*, 9 8 and 11 3 consist of almost as large a number of individuals. Hence in this case 8·3 to 11·3 may be taken as the mode. The extreme cases of yield observed were 5·3 and 17·3 grams. (Plate X, Fig. 1 A.)

The grain size. The size of individual grains affects to a large extent the total yield of earheads. There is a great deal of variation found in the size of grains, depending both on external and internal factors. This variation was studied in the case of fifty earheads grown under normal conditions during the year 1921. None of these represented any extremely small-grained heads and hence the study

can be expected to give only a limited idea of the variation found in the normal crop. The size of grains has been indicated by the number that go to make one gram. The results are shown in the Table below :—

No. of grains per 1 gram	90	100	110	120	130	140	150	160
No. of earheads. Total 150	5	8	13	17	8	2	1	1
Percentage	10	16	26	34	6	4	2	2

One hundred and twenty grains usually go to make up one gram. (Plate X, Fig. 1 B.)

The ratio of size of head to grain yield. It is quite essential to have some idea as to the amount of grain that one should expect out of a particular sized earhead. In order to ascertain this ratio, one hundred earheads of various sizes from the Deccan variety were selected and weighed. The weight of grains obtained from each of these was expressed in terms of percentage of the weight of the earhead. The results are shown in the Table below :—

Grain percentage	43	48	53	58	63	68	73	78	83
No. of heads. Total 100	1	2	1	3	13	18	33	23	6
Percentage	1	2	1	3	13	18	33	23	6

Seventy-three per cent. is the most frequent proportion of grains found in earheads. The maximum has reached eighty-three per cent. of the weight of the earhead. (Plate X, Fig. 2 A.)

Variation in grain size in different parts of earheads. This was studied in the case of fifty earheads selected from the Deccan variety. Each earhead was divided into three equal lengths, and the grains from each part were counted and weighed. The results, as shown in the following Table, indicate the average weight of grains in different parts and also their size expressed as the number going to make up one gram.

Parts of earheads	Lower one-third		Middle one-third		Upper one-third	
	Average Weight gms.	No. per gram	Average Weight gms.	No. per gram	Average Weight gms.	No. per gram
	3·84	113·4 or 8·82 mg. each.	4·55	111·9 or 8·94 mg. each.	2·44	124·5 or 8·03 mg. each.
Per cent.	35·5		42·0		22·5	

The maximum quantity and size of grains is found in the middle one-third of earheads. The quantity and the size diminishes in the lower one-third and it is the least in the upper one-third. The average size of grains in the whole of earhead was 115·5 grains per gram or 8·66 milligrams each. (Plate X, Fig. 2, B.)

Varieties of Bajri.

Mollison[1] and Gammie[2] have each described the same five varieties of this crop as being grown in the Bombay Presidency. The distinctions between these varieties are somewhat marked. There is at least one more variety not included in the above descriptions which is very late and is grown in the Bijapur and Belgaum Districts.

Besides these five or six, there are many so-called varieties grown all over the Presidency often called after the names of localities in which they are being grown. Various qualities are at times attributed to these, but they do not always turn out to be true when they are tested in a different place. Akola *bajri* is probably one of these, but it is very popular in the Deccan as an early and high yielding *bajri*.

No botanical description of any of the above varieties seems to have been given anywhere. If any attempt is to be made it is necessary to describe these while growing in their own locality. About thirty lots of seed of this crop were obtained from different parts of the Bombay Presidency and grown at Poona during the last four years (1922 to 1925) to study their behaviour. Each was grown in a single row thirty to forty feet long. The seed, wherever possible, was obtained from a single earhead during the first year and from a bagged one in subsequent years. The progeny was studied for various morphological characters including detailed observations on the earhead and grain. A short account of this study is given below :—

Sind varieties. Two varieties from Mirpurkhas in Sind, of which one was what is popularly termed " awned " (but really long bristled), were grown in Poona during 1923, 1924 and 1925. The awned one produced long and moderately thick earheads bearing large grains. The leaves of this type in most cases possessed hairs at the base, some of them having hairs on the lamina and sheath in addition, while the remainder had no hairs at all. The other variety produced a smaller earhead and smaller grains too. The leaves were mostly hairy at the base except in a few instances in which they were glabrous. Both varieties possessed long bristles, but the number of such earheads was much greater in the awned than in the other. Thus, neither of the two varieties behaved as a pure stock in respect of bristle length. The big grain awned variety, however, suggests its origin from the Jabalpuri, described below :

[1] J. MOLLISON. Text book on Indian agriculture Vol III (1901).
[2] G. A. GAMMIE. Field and garden crops of the Bombay Presidency. Department of Agriculture, Bombay, Bulletin No. 30 of 1908.

The Jabalpuri, Bhavnagari or Giant bajri. This variety has been described by Mollison as having coarse stalks and long thick spikes of large grain. Gammie says that it possesses grayish-purple bristles equalling or exceeding the spikelets. Seed of this variety was obtained from Cutch and Bhavnagar and grown separately during the last four years. Another variety by name *Bajro* was also tried, but the name was found later to be an additional synonym for the above.

All the above varieties during the four years produced long and very thick earheads having large grains. The leaves were either glabrous or hairy at the base, but in the case of *Bajro* some plants possessing fully hairy leaves were also found. The thickness of earheads in this variety is chiefly due to the greater length of the rachillæ and hence leads to less compact earheads.

Malbandro or Madhodri. Mollison says that this variety gives finer straw than *Bajro* and remarks that it is probably an offshoot from the *Deshi* variety of Gujarat. Gammie states that it differs from the last described in "The thinner and shorter grayish-purple spikes and in the more membranous glumes."

This was grown for the last four years and has produced long and thick earheads having large grains. The leaves presented all types of hairiness and complete absence of hairs as well. The plants showed a closer resemblance to Jabalpuri than to the *Deshi* variety.

Nadiad or Deshi variety. Mollison has described this variety as being perhaps more vigorous in growth than *Malbandro,* but the spikes, he says, are thinner and shorter and are dull light brown.

Four different earheads of this variety were grown separately during 1922, but only one was retained from 1923 onwards. Besides these some seed under the name *Gajwel* was also obtained from the Nadiad and Kapadwanj Talukas of the Kaira district and grown here during the last four years. All of these produced very long and thin cylindrical heads of a compact nature. The grains were fairly large. Leaves of all the usual types in respect of hairiness were present. The rachillæ are inclined to be very short in this variety and this accounts for the thinness and greater compactness of earheads. In some cases extremely long and very thick rachides are also met with.

Awned variety. Mollison refers to this variety as being sparingly grown near Petlad (near Baroda) in Gujarat and also in the Ahmednagar District. It is doubtful as to whether this exists as an independent variety. Long bristles may be found in all types of *bajri* to a smaller or greater extent. This character though heritable has not been found to be present in all progeny derived from a single earhead. None of the awned varieties tried so far have shown any distinct characters other than those that are described under different varieties.

The Deccan bajri. Mollison rightly described this *bajri* as being not so tall as other varieties and says that it produces short and thin spikes containing small seed. He further adds that it is a hardy variety which resists unfavourable conditions better than other varieties. Several samples of this variety each with different

ascribed qualities were tested during the last four years, but none ot them have given any perfectly definite characters. Akola *bajri* has, however, showed its tendency to be slightly earlier than any of the other varieties tried so far. A sample of seed obtained from Dhulia as that of a drought-resistent and heavy-yielding type did not show any indications to that effect. Still another one from Dhulia suspected to be dwarf and early and to produce small earheads did not inherit any of these qualities. A sample from Kopargaon said to be earlier than Akola showed, on the other hand, a tendency to be slightly late. Two more samples Sajugri and Sajugra from near Pandharpur—the former described to be early, long and large grained and the latter, to be late and small-seeded—did not tally even to the seed descriptions and when grown in 1924 did not prove to be true to any of the ascribed characters. Lastly, one more head brought in 1924 from Kusamba near Dhulia and which resembled the Nadiad variety, flowered late and produced long earheads resembling the parent.

Karnatak variety. This has not been described by either Mollison or Gammie. It is quite a distinct variety different from any of those described above. It is grown chiefly in the Bijapur and Belgaum Districts of this Presidency. The plants are tall and thick-culmed producing long wide leaves very much resembling those of *Jowar*. They have a distinct spreading habit and produce many tillers. Flowering commences usually two to three weeks later than in the Deccan variety. Very long and thick earheads are often produced but the grains are not very large. Awned heads are also found mixed up in this crop. No other variety tested so far has remained so faithful to its characters as this one.

Coimbatore varieties. Two varieties were obtained from Coimbatore which are being grown since 1922. The first of these is a rainfed crop known as *Aravathan Cumbu* (*i.e.*, 60 days *Bajri*) which is sown in its native tract in September or October and harvested three months and half later, *i.e.*, in December or January. This, in comparison with the Deccan *bajri*, is found to be late by a fortnight. The other one is *Thirupathi Cumbu*, a short duration variety, sown in garden lands usually in the month of April and watered three or four times during its growth. This is found to be slightly earlier than *Aravathan Cumbu* but not in any way superior to the Deccan variety from the point of earliness.

Both of these possess long, narrow leaves, tender in appearance. The culms are somewhat thin and do not attain any great height. The earheads are long and cylindrical but much reduced in thickness. The grains are usually elongated being much smaller than those of the Deccan *bajri* and remain almost completely enclosed within the glumes. None of these appear to be hardy enough to suit the Deccan conditions.

African varieties. Two varieties, one named Bulrush and the other African, were obtained from the Agricultural College Farm, Poona, and grown during the last four years. The first of these contained a large proportion of awned heads in its progeny and the leaves being directed upwards were quite different from those

of the Deccan *bajri*. A third variety called Nigerian was brought from Mirpurkhas in 1923 and tried here for three seasons. This also produced a large proportion of awned heads. The leaves of this variety possessed no hairs either at the base of the lamina or on the sheath and lamina in general. The earheads in all the three varieties were medium sized, but the grains in the Nigerian were slightly smaller than in the other two.

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